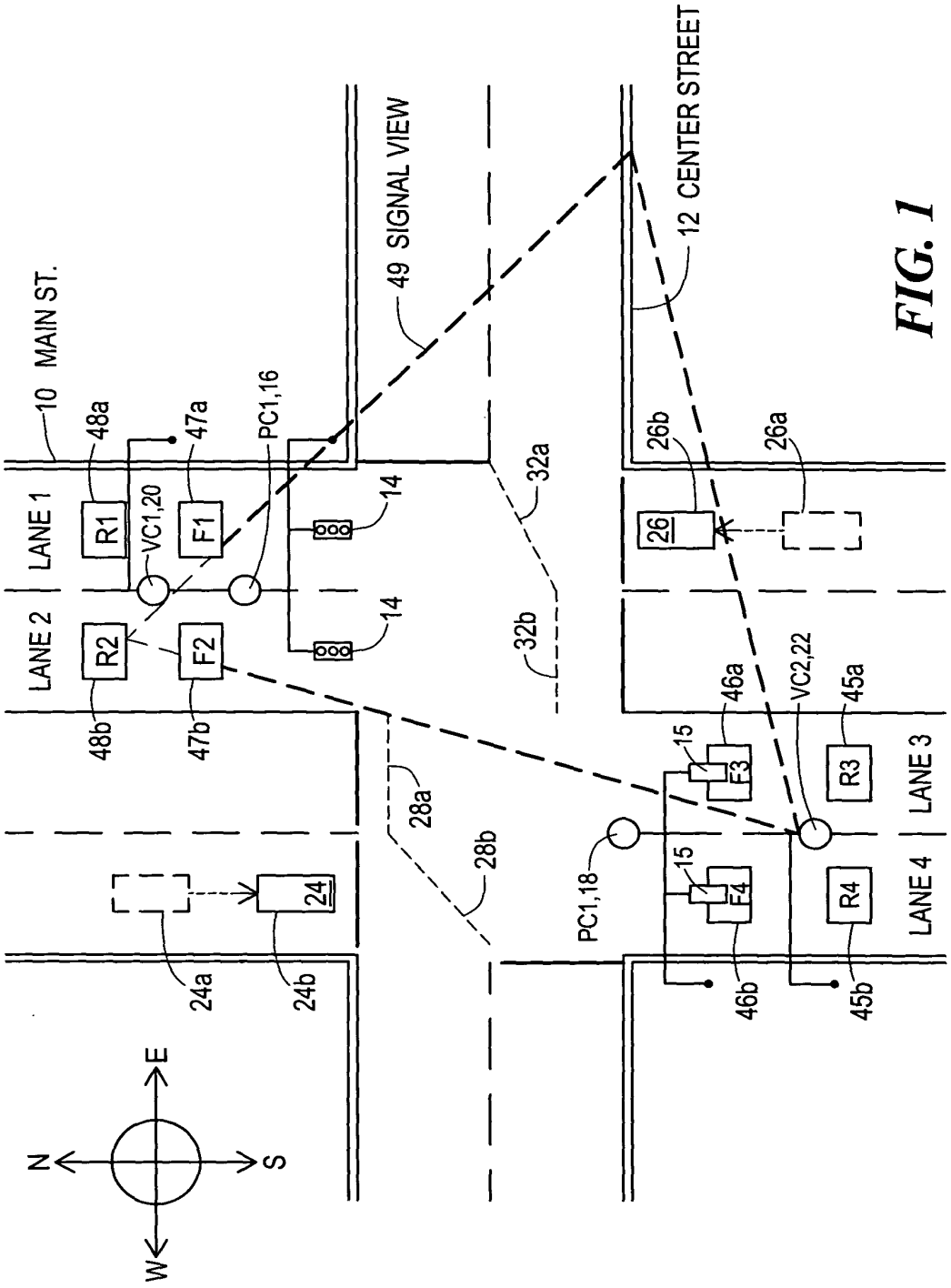

10 MAIN ST.
49 SIGNAL VIEW
12 CENTER STREET
LANE 1
LANE 2
LANE 3
LANE 4
R1
R2
R3
R4
F1
F2
F3
F4
VC1,20
VC2,22
PC1,16
PC1,18
48a
48b
47a
47b
46a
46b
45a
45b
14
15
24
24a
24b
26
26a
26b
28a
28b
32a
32b
N
S
E
W

FIG. 1

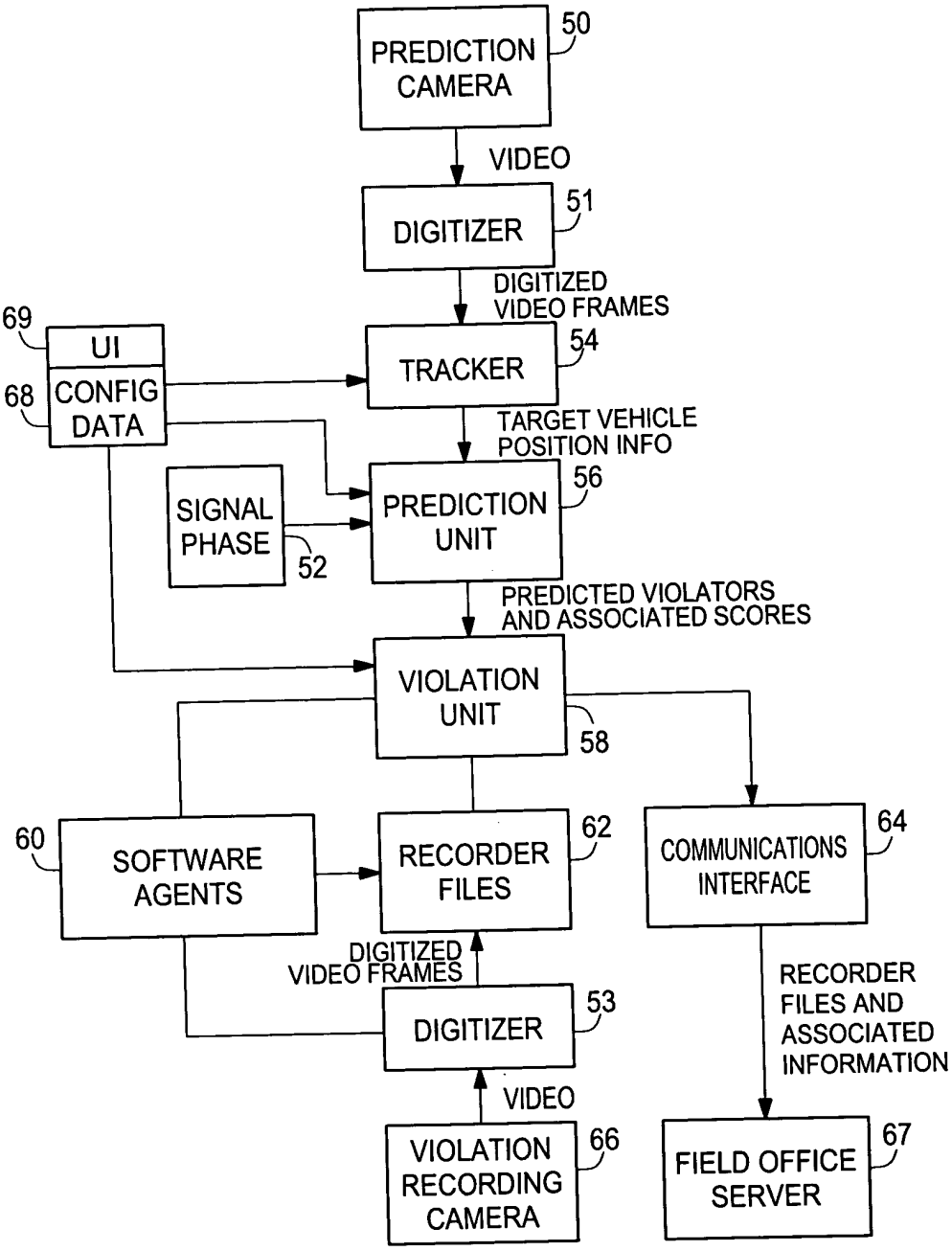

PREDICTION CAMERA
50
VIDEO
DIGITIZER
51
DIGITIZED VIDEO FRAMES
69
UI
68
CONFIG DATA
TRACKER
54
TARGET VEHICLE POSITION INFO
SIGNAL PHASE
52
PREDICTION UNIT
56
PREDICTED VIOLATORS AND ASSOCIATED SCORES
VIOLATION UNIT
58
60
SOFTWARE AGENTS
RECORDER FILES
62
COMMUNICATIONS INTERFACE
64
DIGITIZED VIDEO FRAMES
DIGITIZER
53
RECORDER FILES AND ASSOCIATED INFORMATION
VIDEO
VIOLATION RECORDING CAMERA
66
FIELD OFFICE SERVER
67

FIG. 2

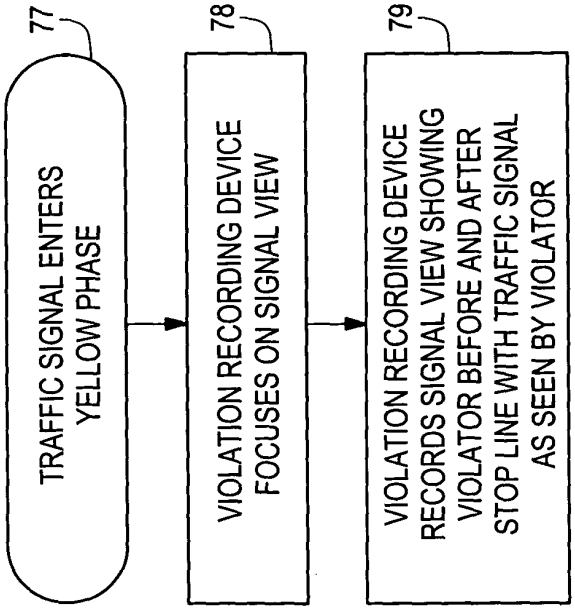

77
TRAFFIC SIGNAL ENTERS YELLOW PHASE
78
VIOLATION RECORDING DEVICE FOCUSES ON SIGNAL VIEW
79
VIOLATION RECORDING DEVICE RECORDS SIGNAL VIEW SHOWING VIOLATOR BEFORE AND AFTER STOP LINE WITH TRAFFIC SIGNAL AS SEEN BY VIOLATOR

FIG. 4

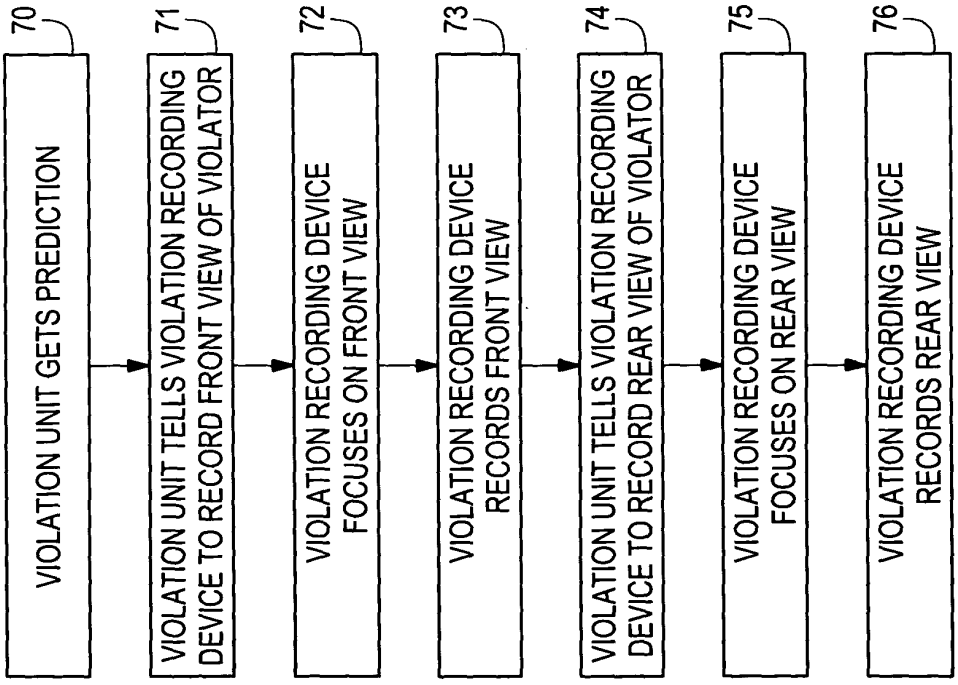

70
VIOLATION UNIT GETS PREDICTION
71
VIOLATION UNIT TELLS VIOLATION RECORDING DEVICE TO RECORD FRONT VIEW OF VIOLATOR
72
VIOLATION RECORDING DEVICE FOCUSES ON FRONT VIEW
73
VIOLATION RECORDING DEVICE RECORDS FRONT VIEW
74
VIOLATION UNIT TELLS VIOLATION RECORDING DEVICE TO RECORD REAR VIEW OF VIOLATOR
75
VIOLATION RECORDING DEVICE FOCUSES ON REAR VIEW
76
VIOLATION RECORDING DEVICE RECORDS REAR VIEW

FIG. 3

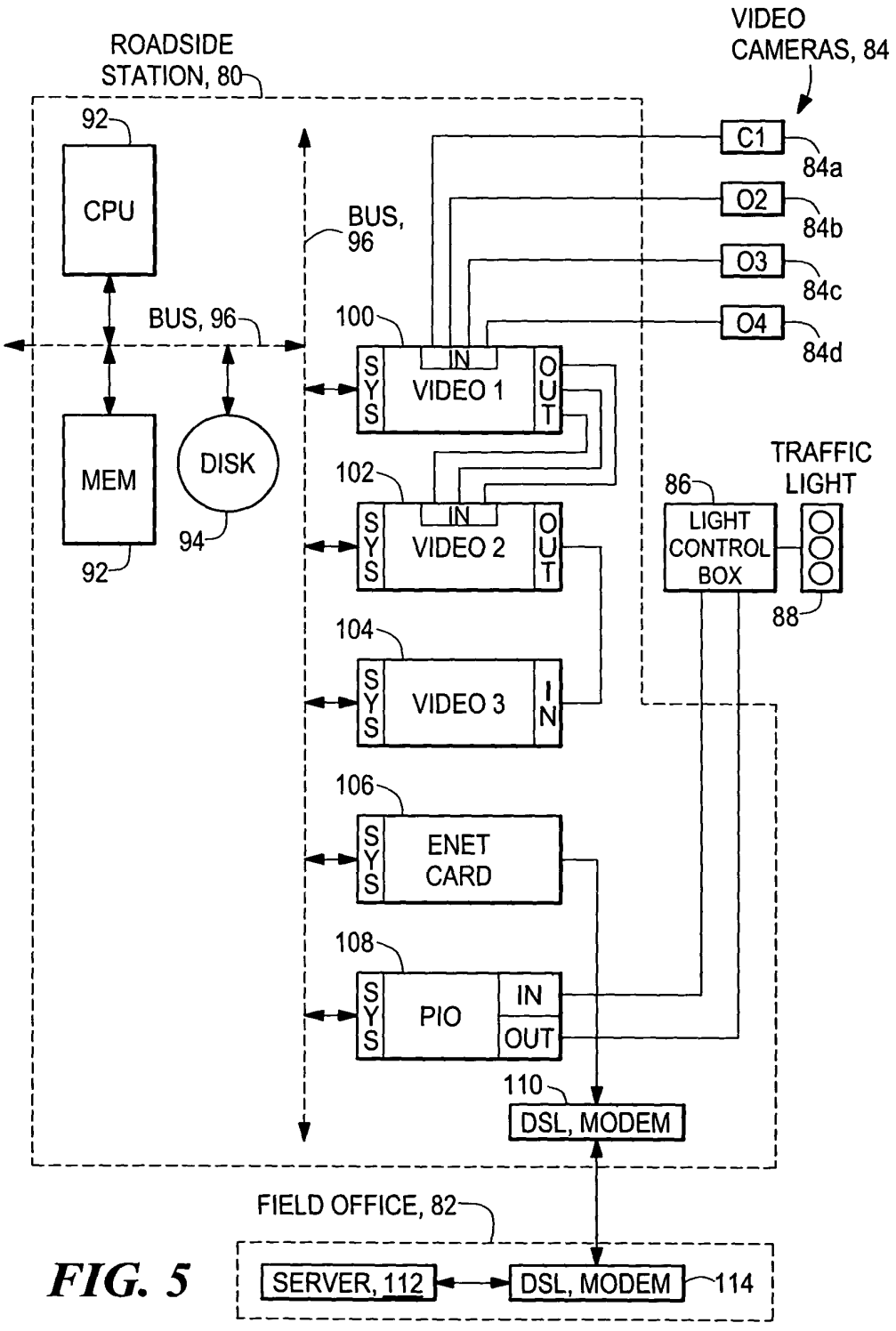

ROADSIDE STATION, 80
VIDEO CAMERAS, 84
92
CPU
BUS, 96
C1
84a
O2
84b
O3
84c
O4
84d
BUS, 96
100
IN
SYS
VIDEO 1
OUT
MEM
DISK
94
92
102
IN
SYS
VIDEO 2
OUT
TRAFFIC LIGHT
86
LIGHT CONTROL BOX
88
104
SYS
VIDEO 3
IN
106
SYS
ENET CARD
108
SYS
PIO
IN
OUT
110
DSL, MODEM
FIELD OFFICE, 82
SERVER, 112
DSL, MODEM
114

FIG. 5

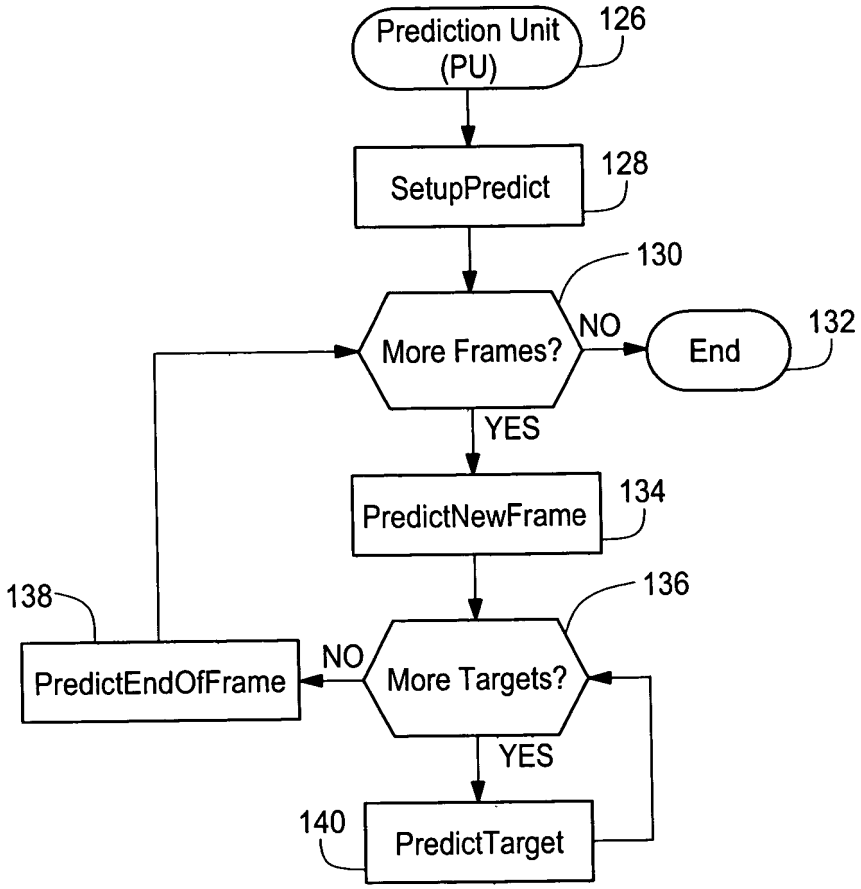

Prediction Unit (PU)
126
SetupPredict
128
130
More Frames?
NO
End
132
YES
PredictNewFrame
134
136
138
PredictEndOfFrame
NO
More Targets?
YES
140
PredictTarget

FIG. 6

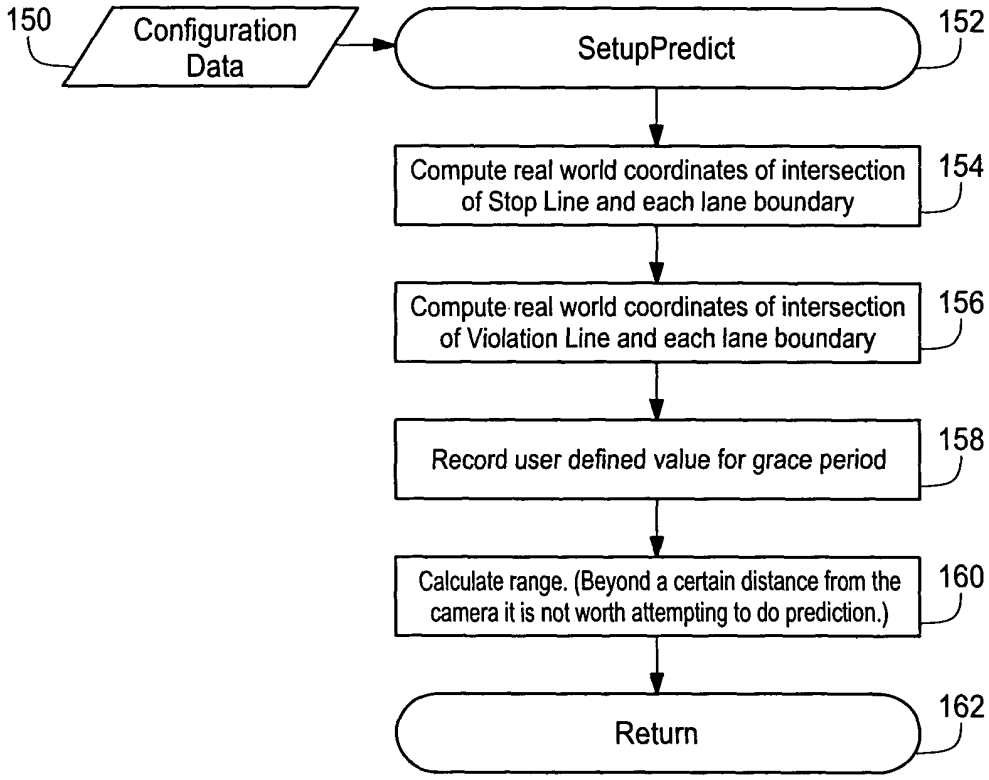

150
Configuration Data
SetupPredict
152
Compute real world coordinates of intersection of Stop Line and each lane boundary
154
Compute real world coordinates of intersection of Violation Line and each lane boundary
156
Record user defined value for grace period
158
Calculate range. (Beyond a certain distance from the camera it is not worth attempting to do prediction.)
160
Return
162

FIG. 7

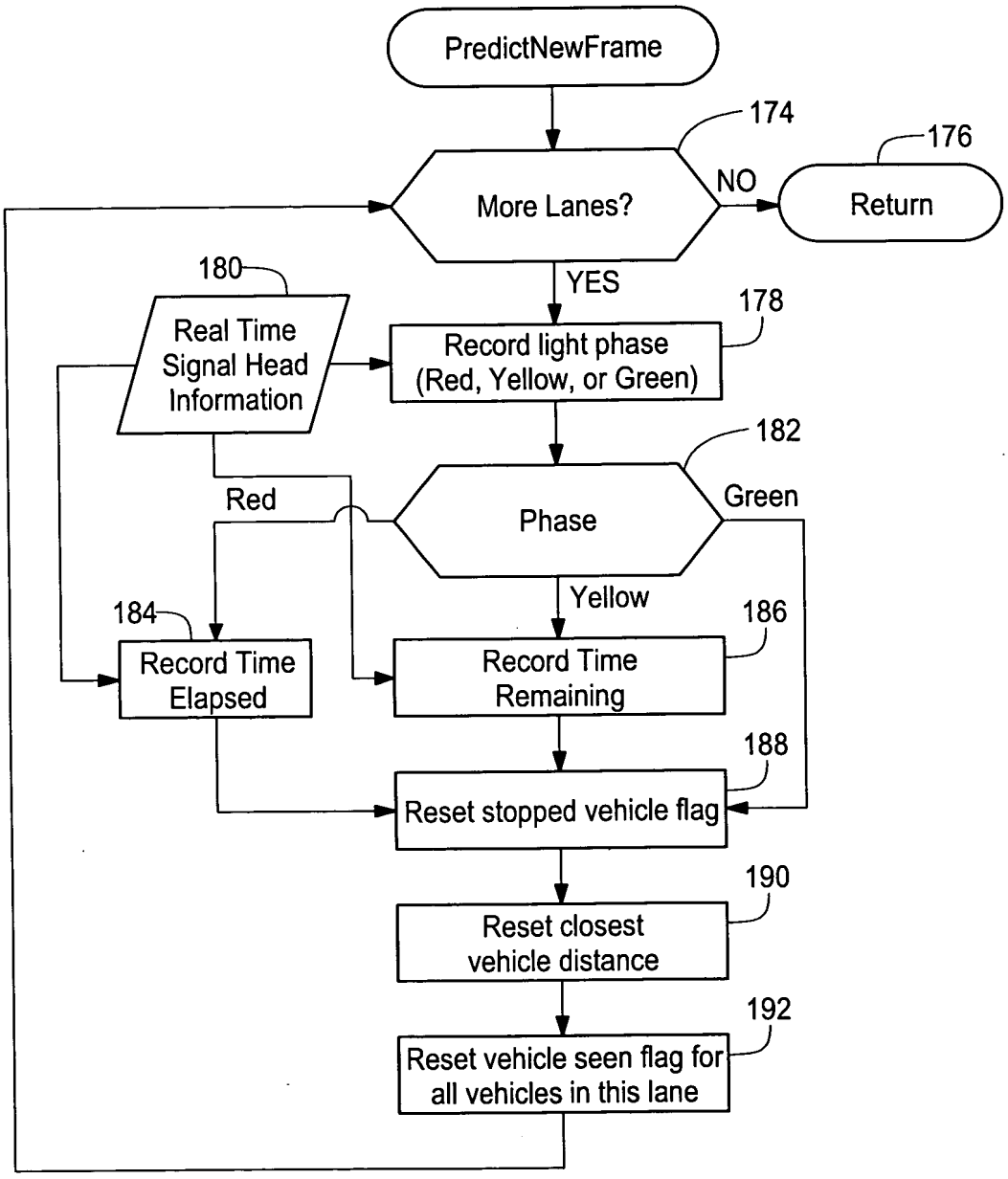

PredictNewFrame
174
More Lanes?
NO
176
Return
YES
180
Real Time Signal Head Information
178
Record light phase (Red, Yellow, or Green)
182
Red
Phase
Green
Yellow
184
Record Time Elapsed
186
Record Time Remaining
188
Reset stopped vehicle flag
190
Reset closest vehicle distance
192
Reset vehicle seen flag for all vehicles in this lane

FIG. 8

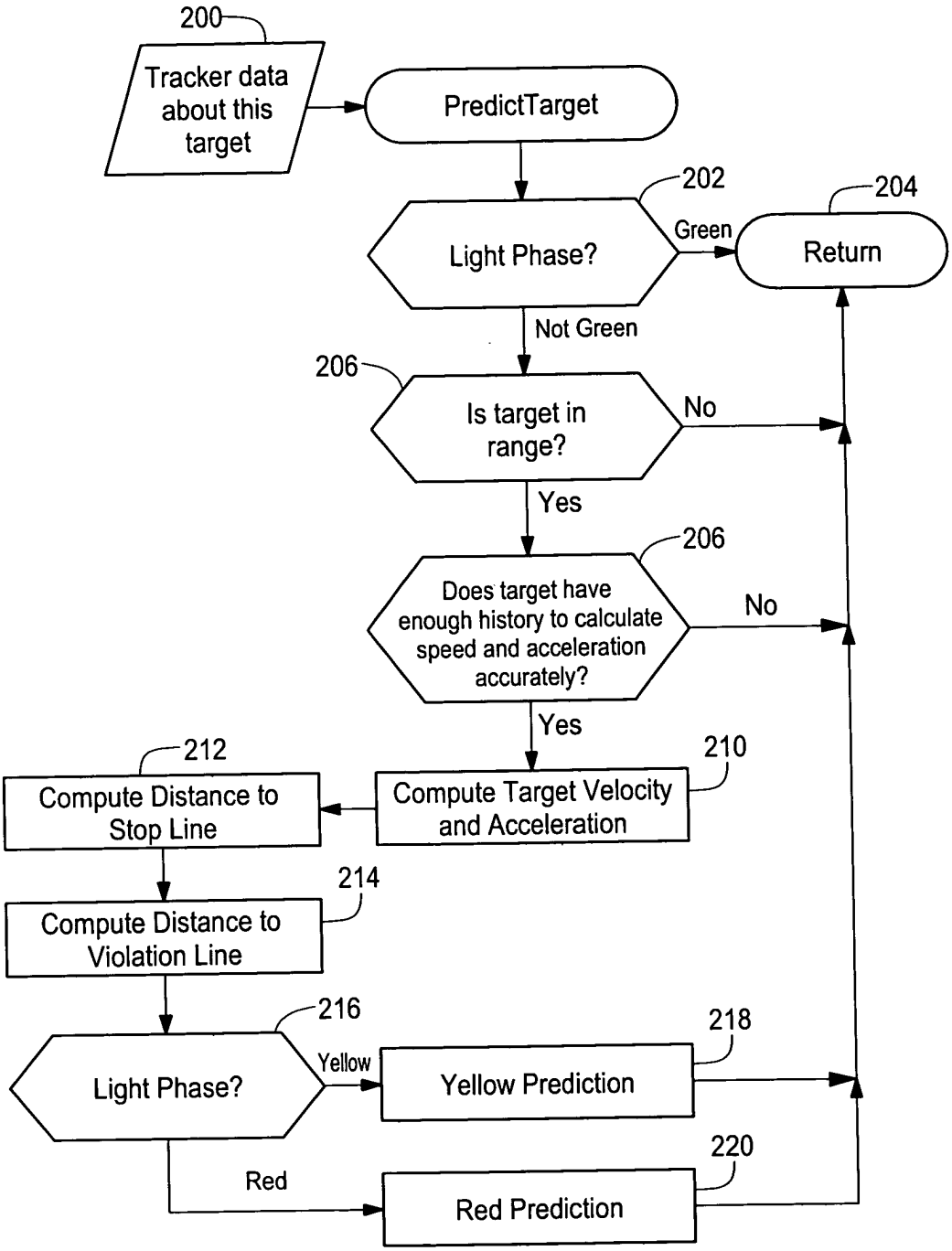

200
Tracker data about this target
PredictTarget
202
Light Phase?
Green
204
Return
Not Green
206
Is target in range?
No
Yes
206
Does target have enough history to calculate speed and acceleration accurately?
No
Yes
212
Compute Distance to Stop Line
210
Compute Target Velocity and Acceleration
214
Compute Distance to Violation Line
216
Light Phase?
Yellow
218
Yellow Prediction
Red
220
Red Prediction

FIG. 9

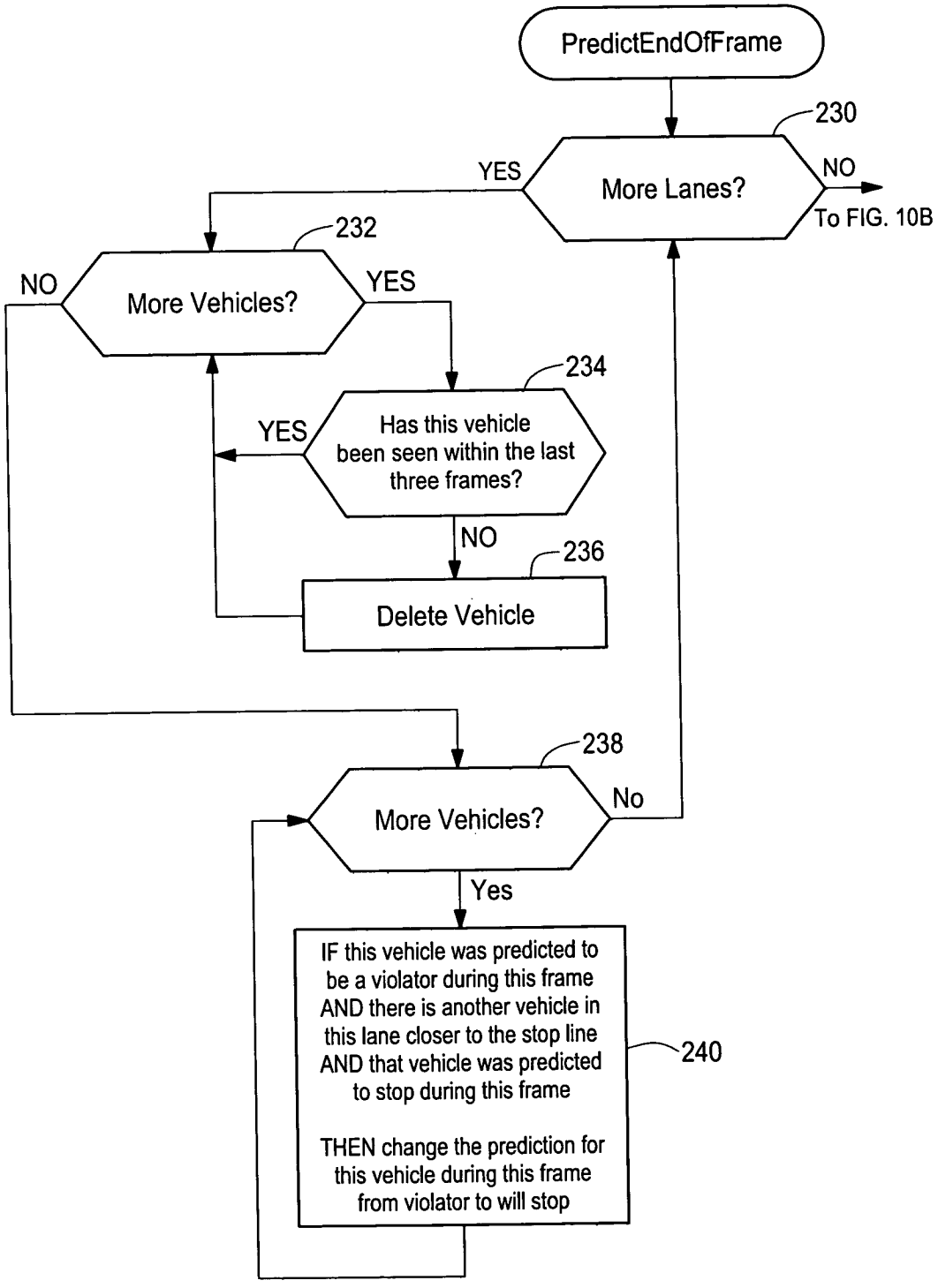

PredictEndOfFrame
230
More Lanes?
YES
NO
To FIG. 10B
232
More Vehicles?
NO
YES
234
Has this vehicle been seen within the last three frames?
YES
NO
236
Delete Vehicle
238
More Vehicles?
No
Yes
IF this vehicle was predicted to be a violator during this frame AND there is another vehicle in this lane closer to the stop line AND that vehicle was predicted to stop during this frame
THEN change the prediction for this vehicle during this frame from violator to will stop
240

FIG. 10A

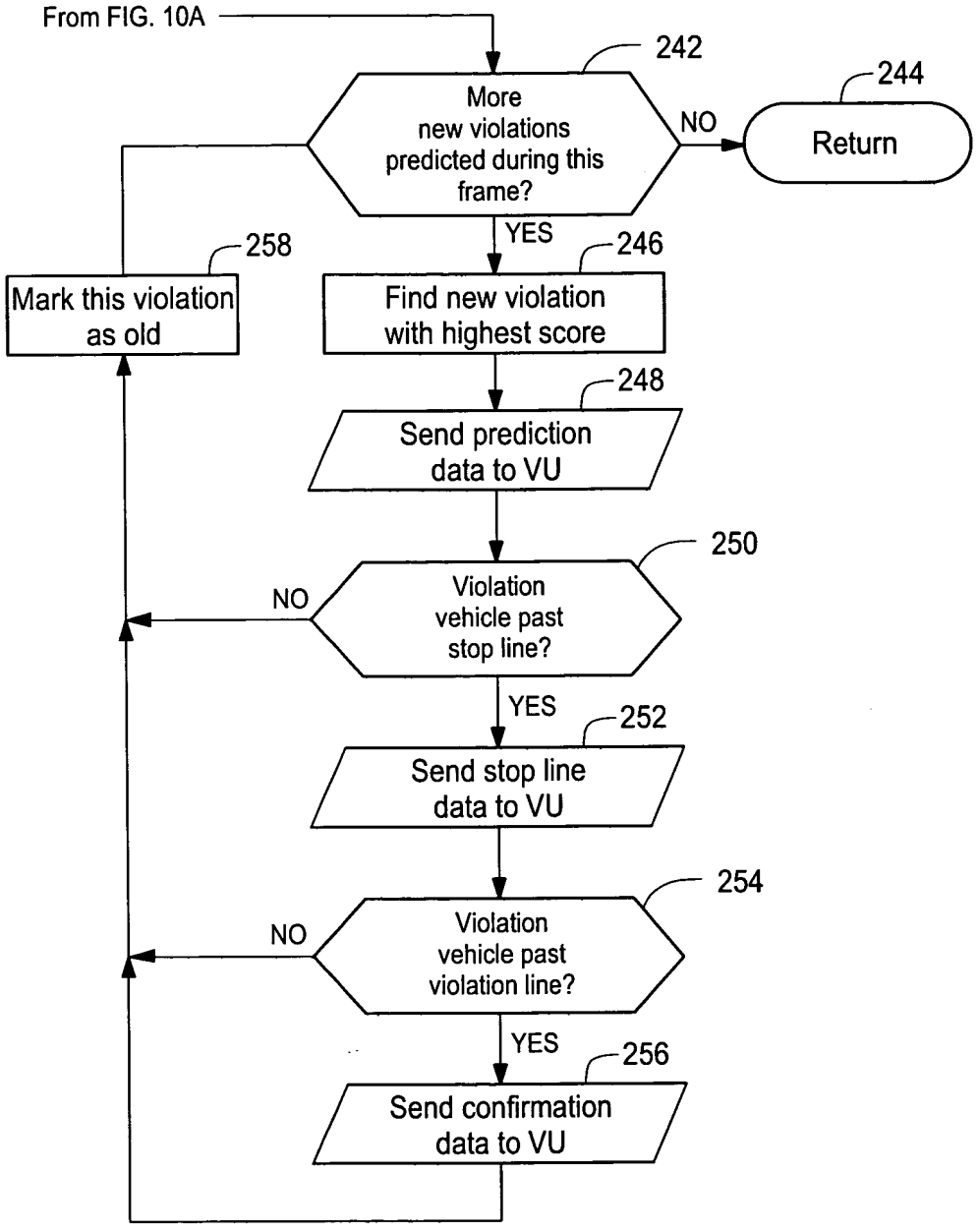
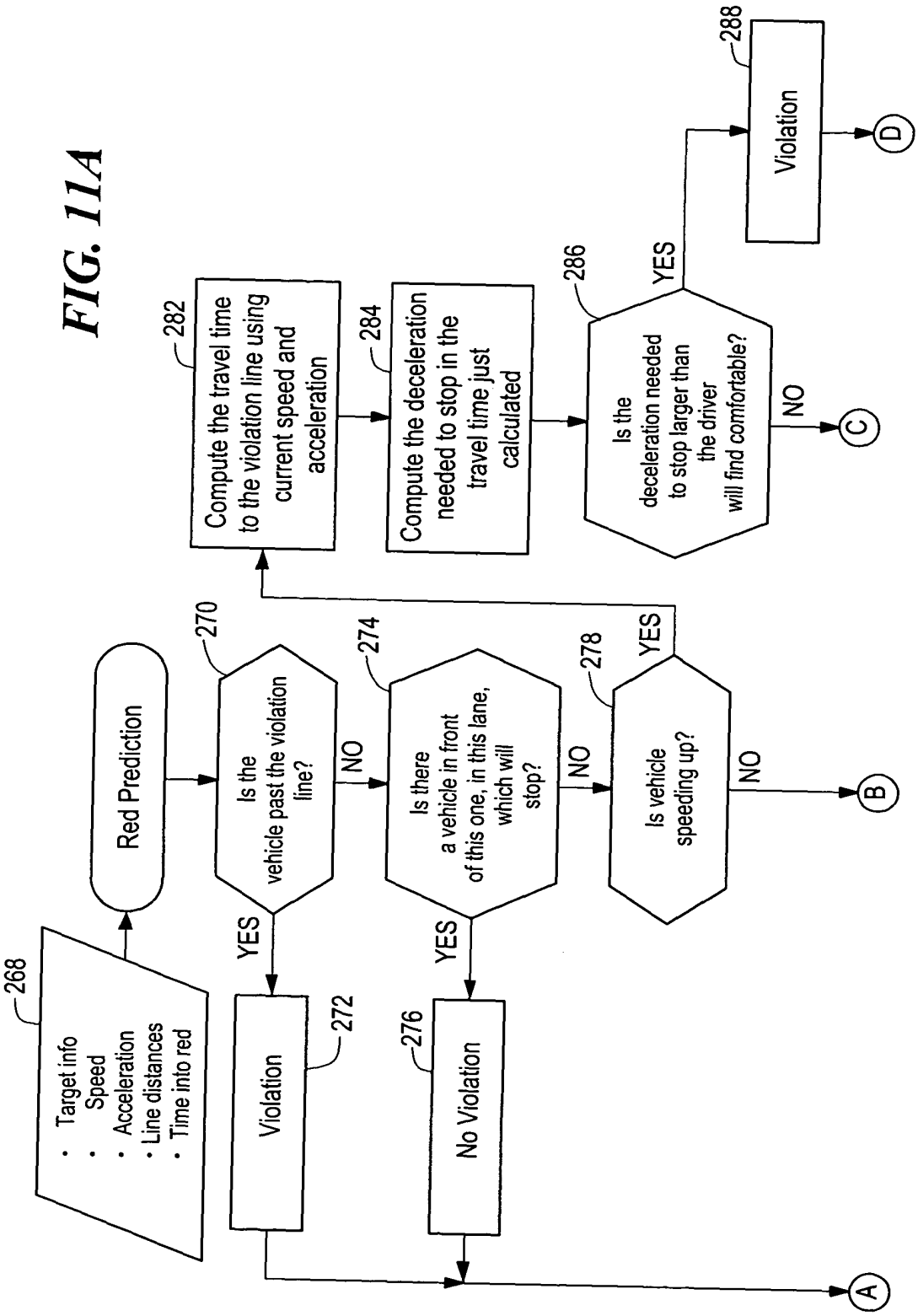

From FIG. 10A
242
More new violations predicted during this frame?
NO
244
Return
YES
246
Find new violation with highest score
258
Mark this violation as old
248
Send prediction data to VU
250
Violation vehicle past stop line?
NO
YES
252
Send stop line data to VU
254
Violation vehicle past violation line?
NO
YES
256
Send confirmation data to VU

FIG. 10B

FIG. 11A


268
• Target info
Speed
• Acceleration
• Line distances
• Time into red
Red Prediction
270
Is the vehicle past the violation line?
YES
NO
272
Violation
274
Is there a vehicle in front of this one, in this lane, which will stop?
YES
NO
276
No Violation
278
Is vehicle speeding up?
YES
NO
282
Compute the travel time to the violation line using current speed and acceleration
284
Compute the deceleration needed to stop in the travel time just calculated
286
Is the deceleration needed to stop larger than the driver will find comfortable?
YES
NO
288
Violation
A
B
C
D

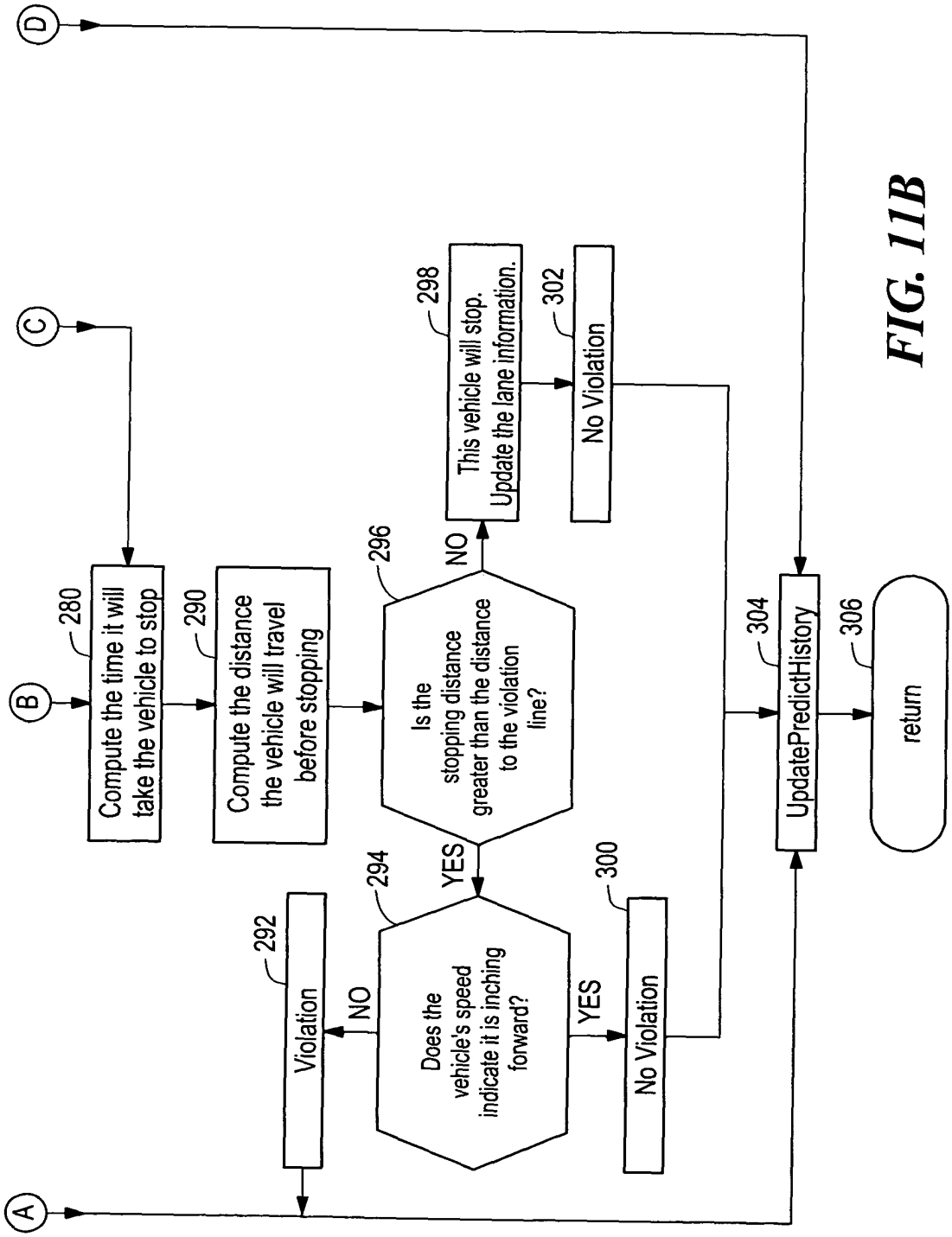

D
C
B
A
280
Compute the time it will take the vehicle to stop
290
Compute the distance the vehicle will travel before stopping
296
Is the stopping distance greater than the distance to the violation line?
NO
298
This vehicle will stop. Update the lane information.
302
No Violation
YES
294
Does the vehicle's speed indicate it is inching forward?
NO
292
Violation
YES
300
No Violation
304
UpdatePredictHistory
306
return

FIG. 11B

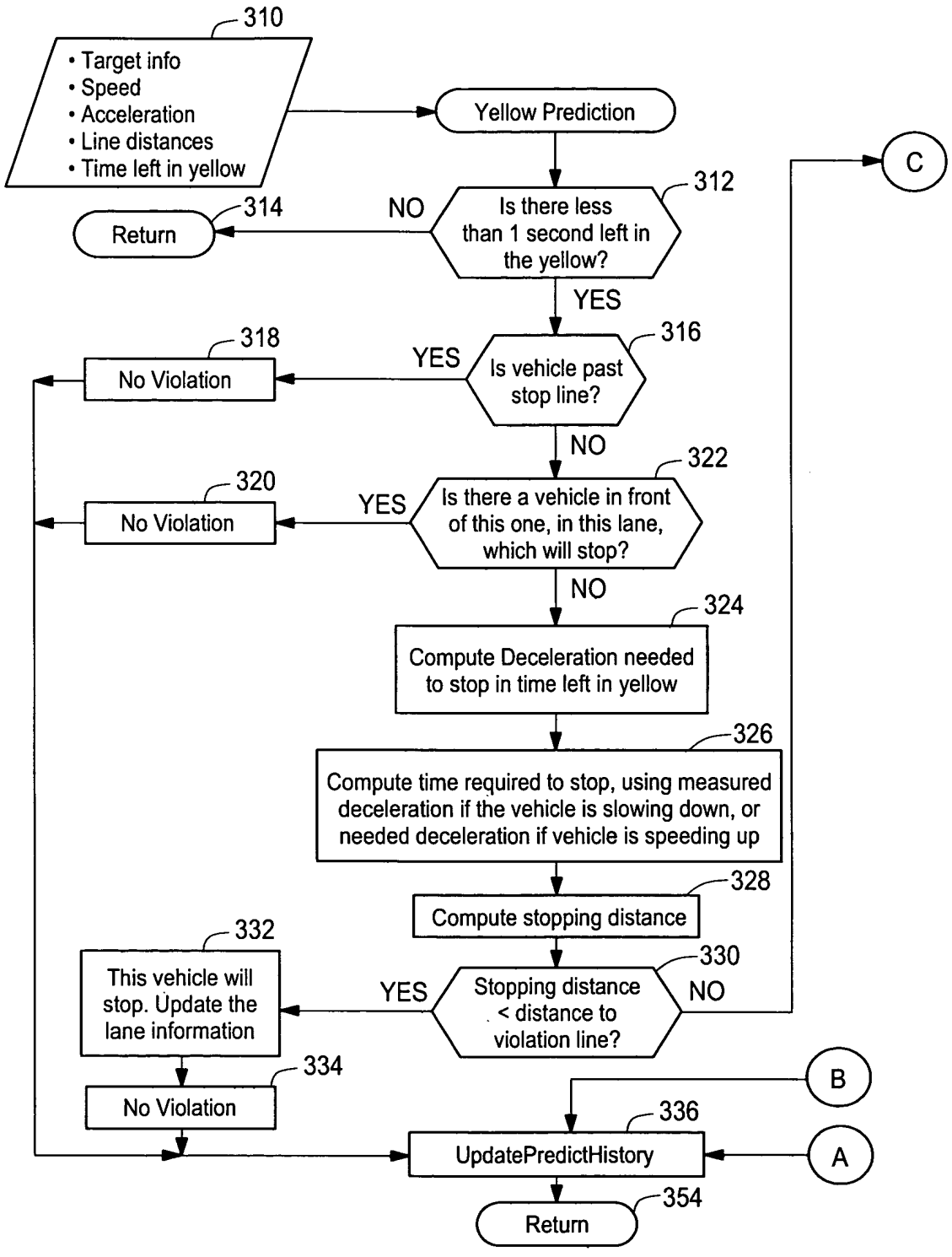

310
• Target info
• Speed
• Acceleration
• Line distances
• Time left in yellow
Yellow Prediction
C
312
Is there less than 1 second left in the yellow?
NO
314
Return
YES
316
Is vehicle past stop line?
YES
318
No Violation
NO
322
Is there a vehicle in front of this one, in this lane, which will stop?
YES
320
No Violation
NO
324
Compute Deceleration needed to stop in time left in yellow
326
Compute time required to stop, using measured deceleration if the vehicle is slowing down, or needed deceleration if vehicle is speeding up
328
Compute stopping distance
330
Stopping distance < distance to violation line?
YES
NO
332
This vehicle will stop. Update the lane information
334
No Violation
B
A
336
UpdatePredictHistory
354
Return

FIG. 12A

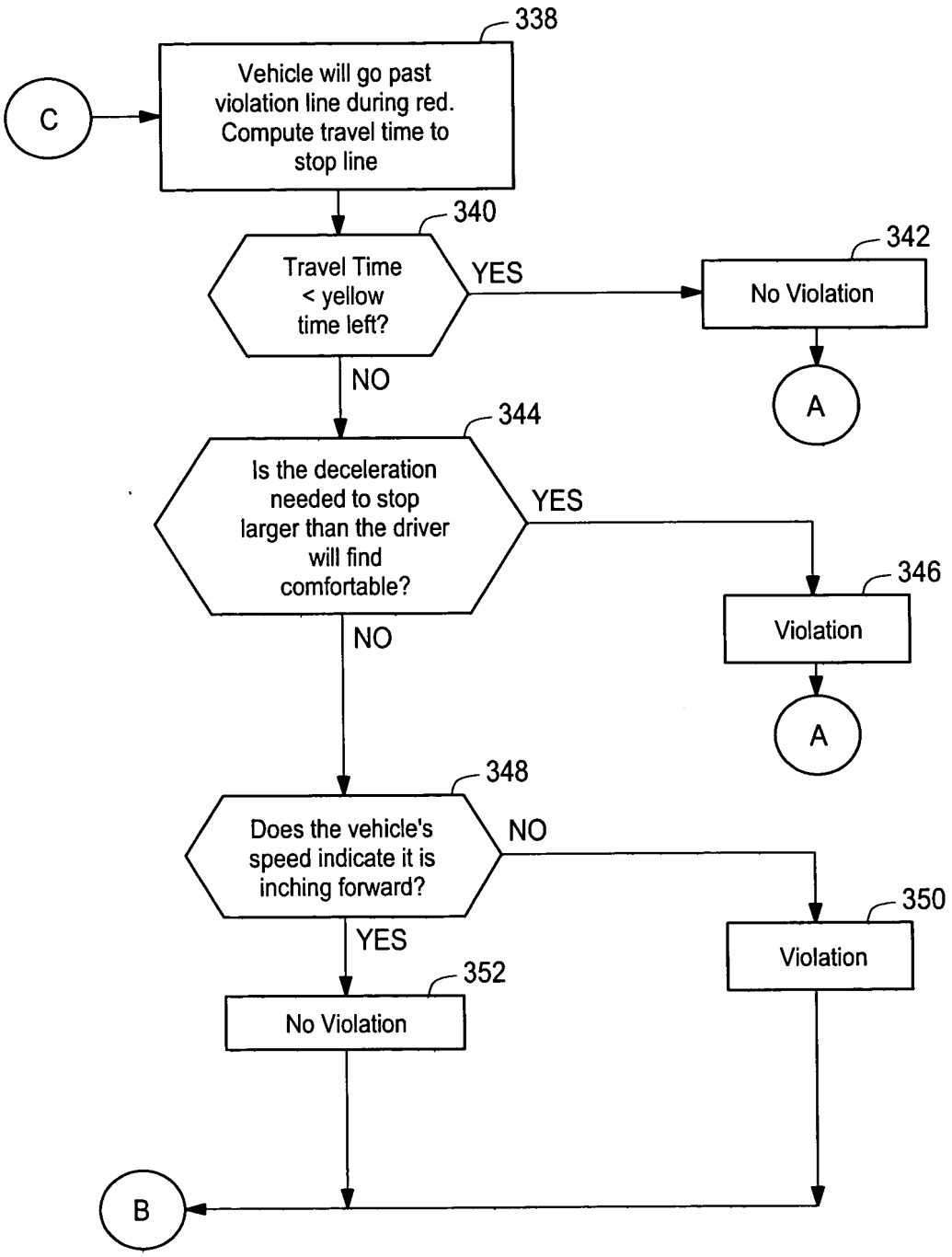

C
338
Vehicle will go past violation line during red. Compute travel time to stop line
340
Travel Time < yellow time left?
YES
342
No Violation
A
NO
344
Is the deceleration needed to stop larger than the driver will find comfortable?
YES
346
Violation
A
NO
348
Does the vehicle's speed indicate it is inching forward?
NO
350
Violation
YES
352
No Violation
B

FIG. 12B

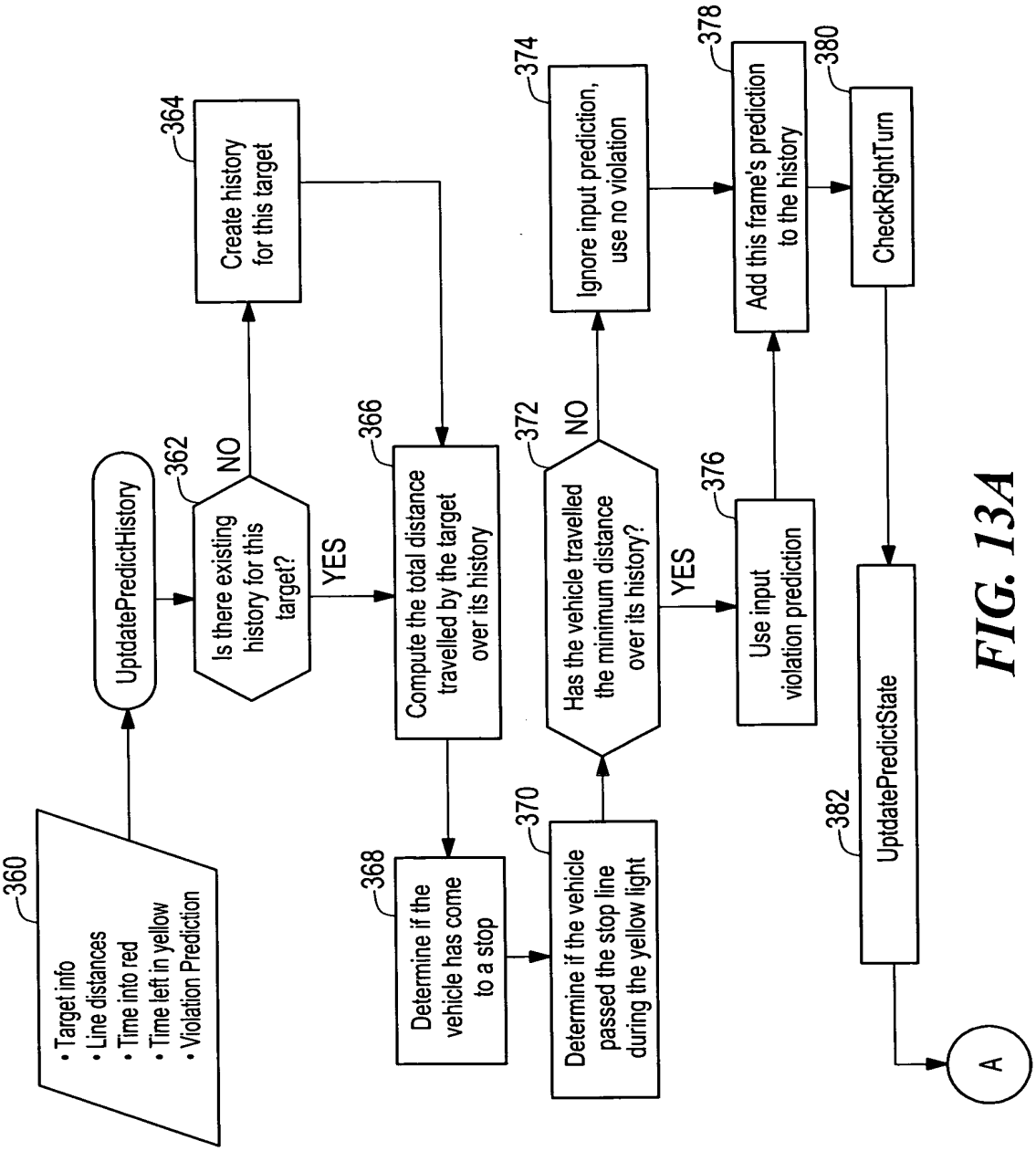

360
• Target info
• Line distances
• Time into red
• Time left in yellow
• Violation Prediction
UptdatePredictHistory
362
Is there existing history for this target?
NO
YES
364
Create history for this target
366
Compute the total distance travelled by the target over its history
368
Determine if the vehicle has come to a stop
370
Determine if the vehicle passed the stop line during the yellow light
372
Has the vehicle travelled the minimum distance over its history?
NO
YES
374
Ignore input prediction, use no violation
376
Use input violation prediction
378
Add this frame's prediction to the history
380
CheckRightTurn
382
UptdatePredictState
A

FIG. 13A

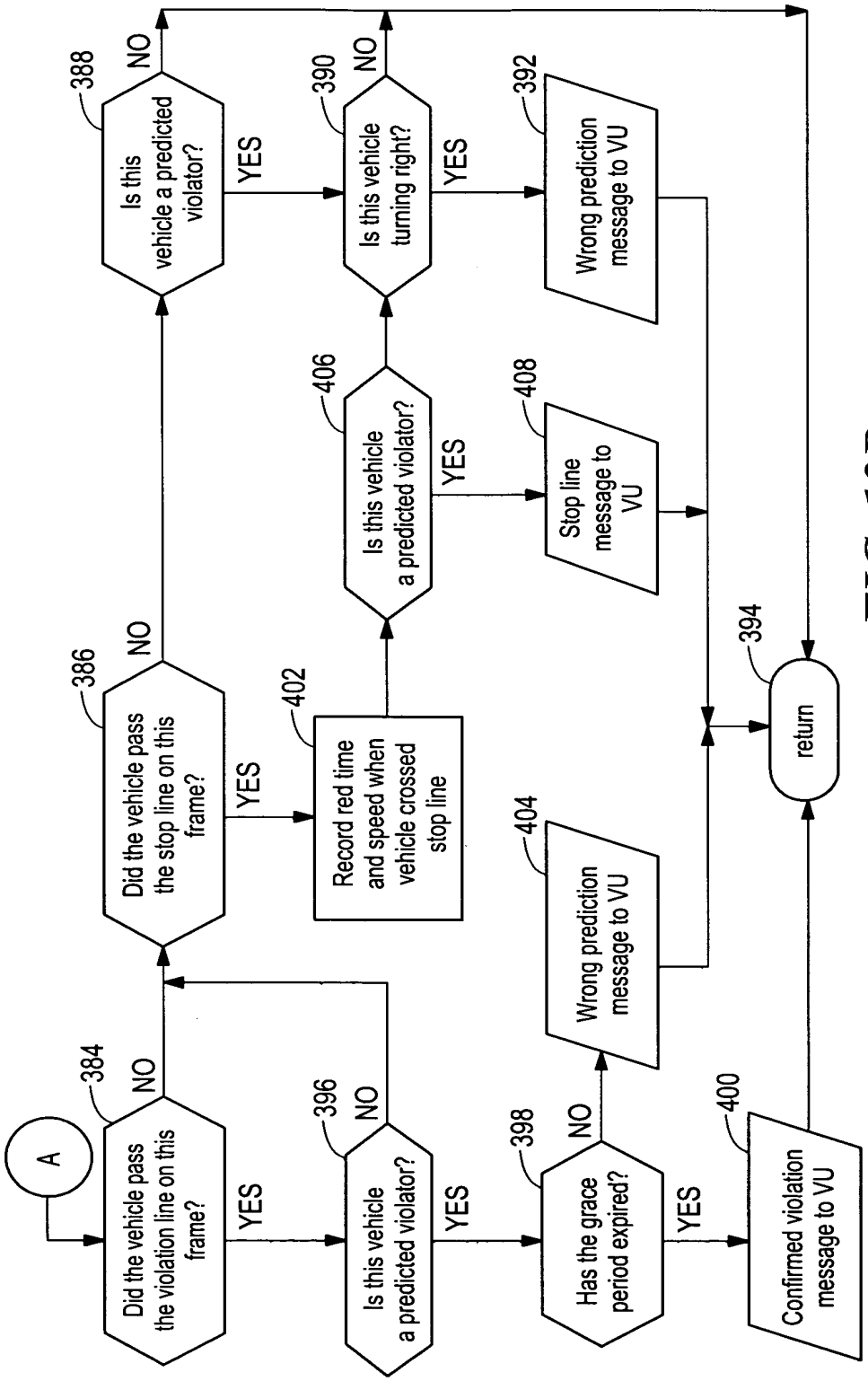
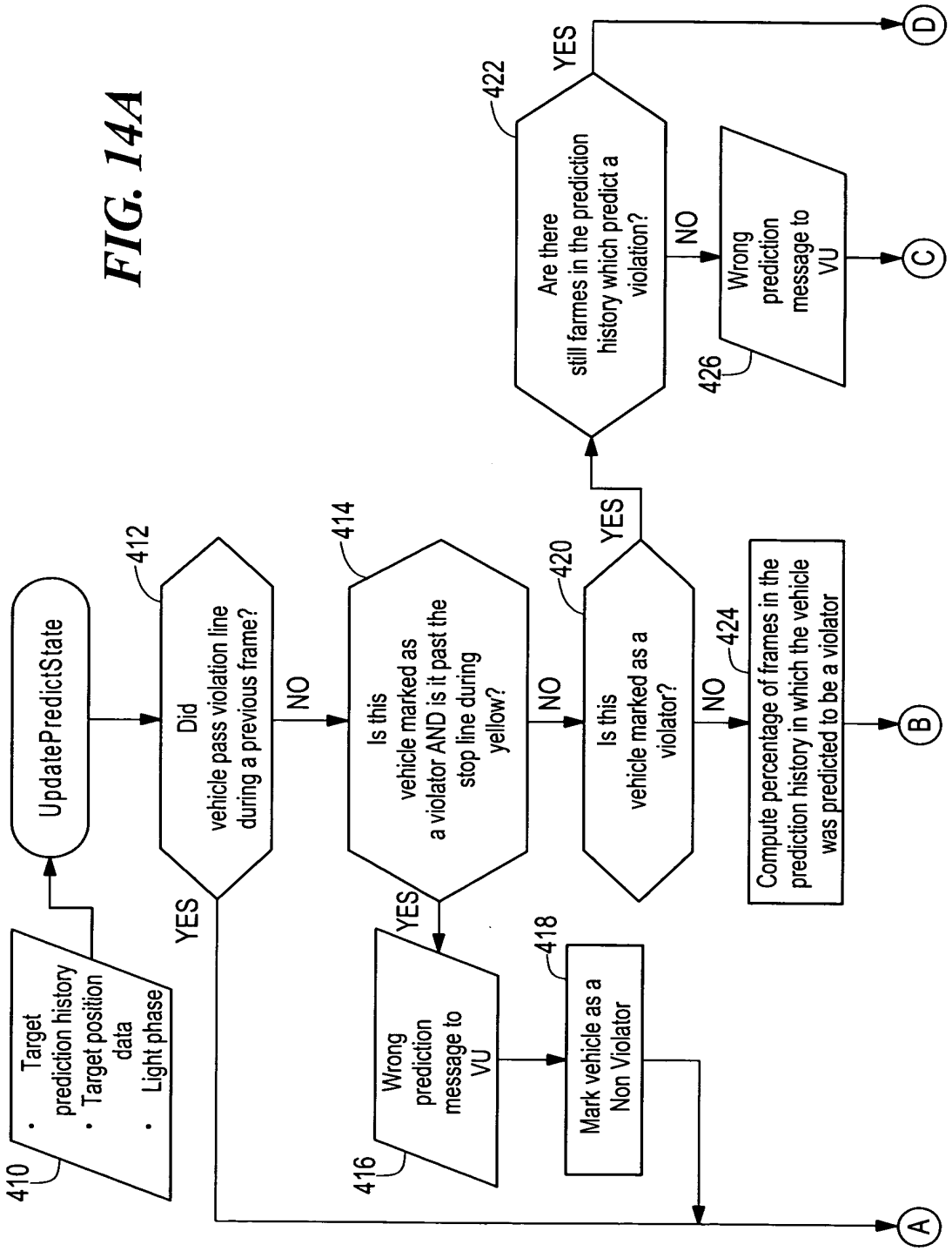

A
384
Did the vehicle pass the violation line on this frame?
NO
YES
396
Is this vehicle a predicted violator?
NO
YES
398
Has the grace period expired?
NO
YES
400
Confirmed violation message to VU
404
Wrong prediction message to VU
386
Did the vehicle pass the stop line on this frame?
NO
YES
402
Record red time and speed when vehicle crossed stop line
406
Is this vehicle a predicted violator?
YES
408
Stop line message to VU
388
Is this vehicle a predicted violator?
NO
YES
390
Is this vehicle turning right?
NO
YES
392
Wrong prediction message to VU
394
return

FIG. 13B

FIG. 14A


UpdatePredictState
Target prediction history
Target position data
Light phase
410
Did vehicle pass violation line during a previous frame?
412
YES
NO
Is this vehicle marked as a violator AND is it past the stop line during yellow?
414
YES
NO
Wrong prediction message to VU
416
Mark vehicle as a Non Violator
418
Is this vehicle marked as a violator?
420
YES
NO
Are there still farmes in the prediction history which predict a violation?
422
YES
NO
Wrong prediction message to VU
426
Compute percentage of frames in the prediction history in which the vehicle was predicted to be a violator
424
A
B
C
D

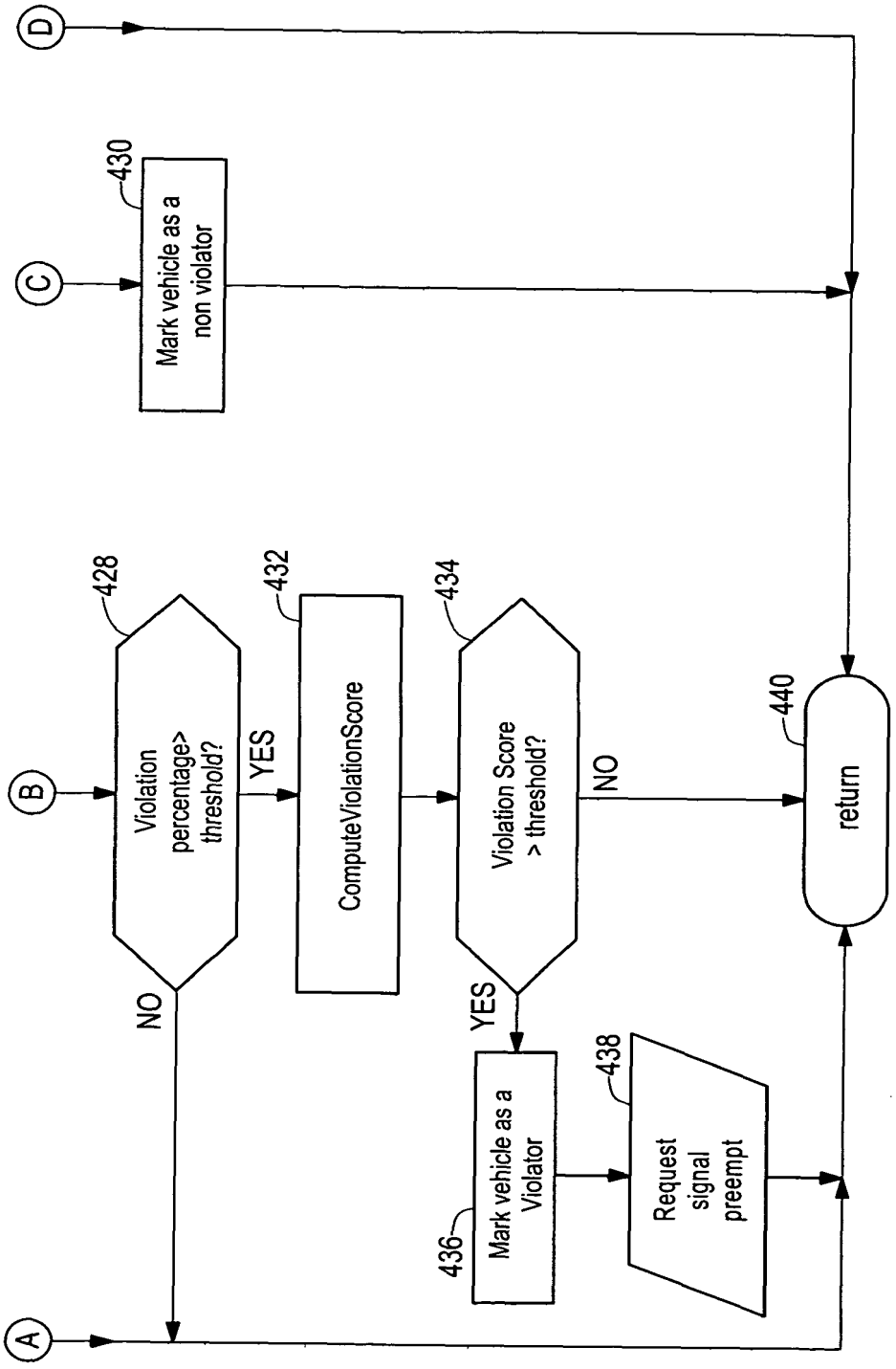
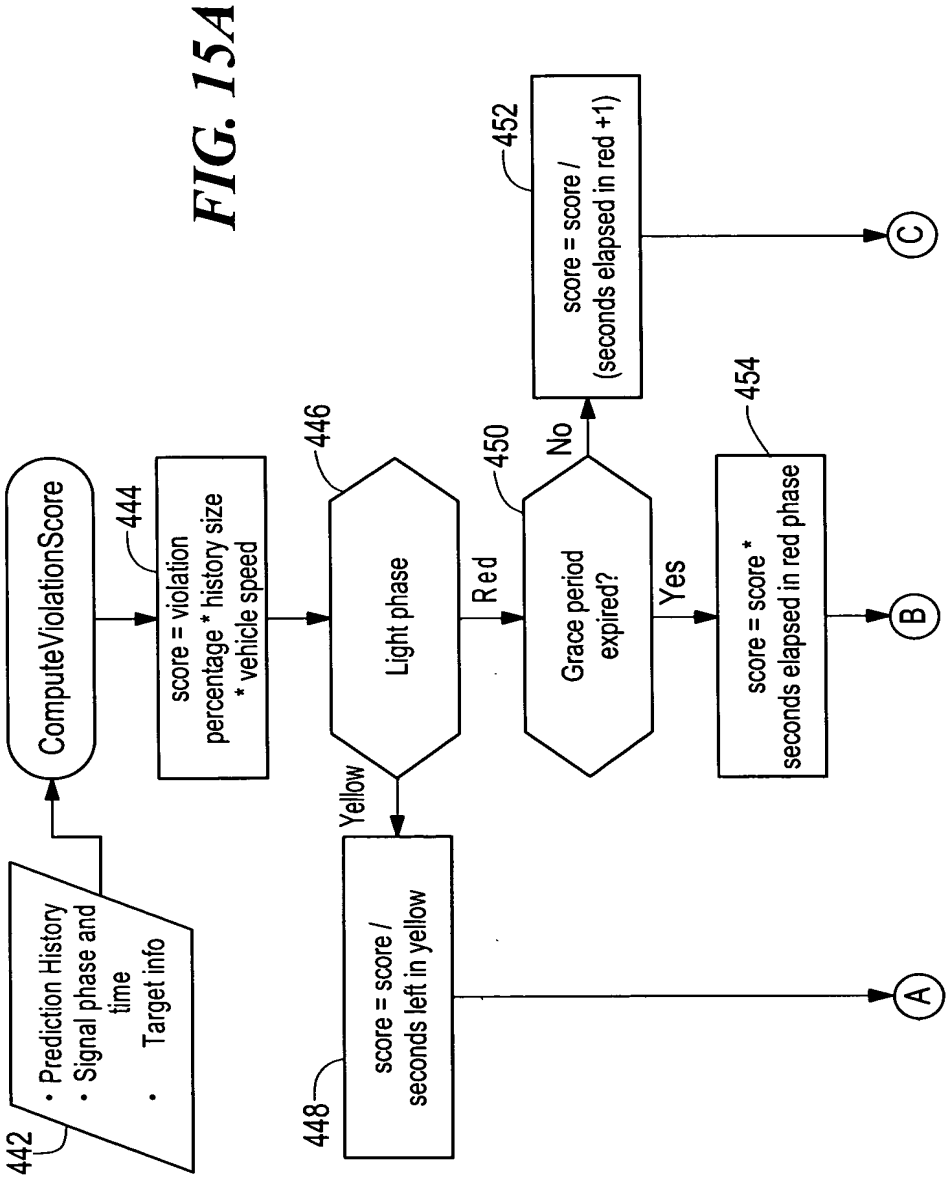

D
C
430
Mark vehicle as a non violator
B
428
Violation percentage> threshold?
YES
NO
432
ComputeViolationScore
434
Violation Score > threshold?
NO
YES
440
return
436
Mark vehicle as a Violator
438
Request signal preempt
A

FIG. 14B

FIG. 15A


ComputeViolationScore
442
• Prediction History
• Signal phase and time
• Target info
444
score = violation percentage * history size * vehicle speed
446
Light phase
Yellow
448
score = score / seconds left in yellow
A
Red
450
Grace period expired?
No
452
score = score / (seconds elapsed in red +1)
C
Yes
454
score = score * seconds elapsed in red phase
B

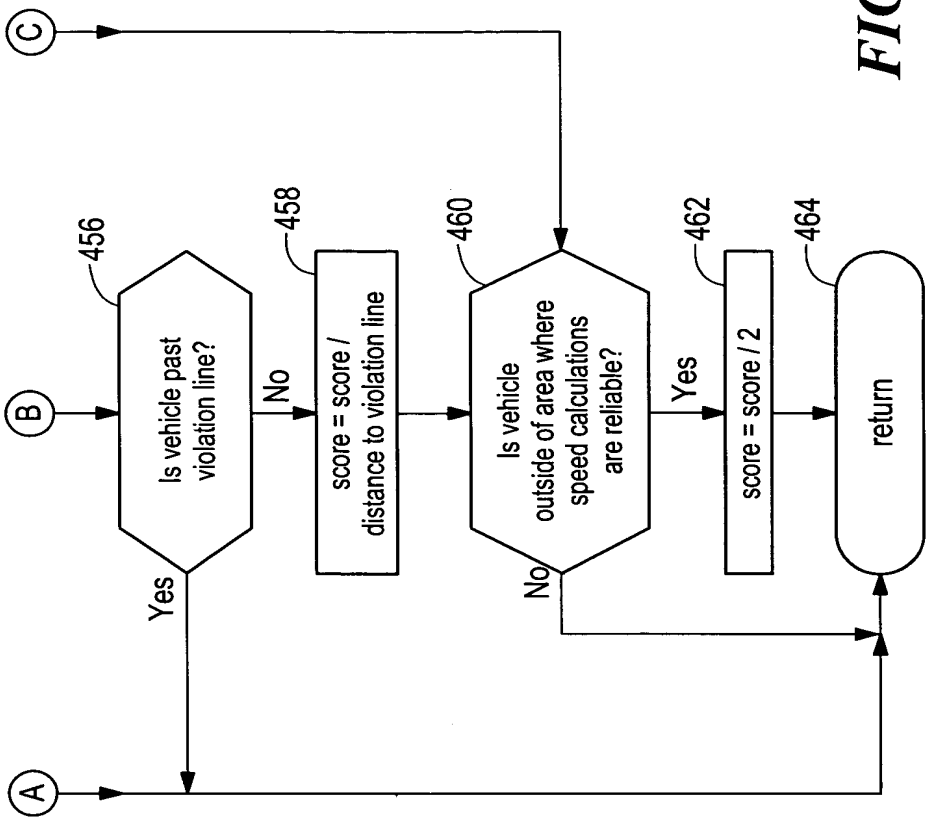

C
B
A
456
Is vehicle past violation line?
Yes
No
458
score = score / distance to violation line
460
Is vehicle outside of area where speed calculations are reliable?
No
Yes
462
score = score / 2
464
return

FIG. 15B

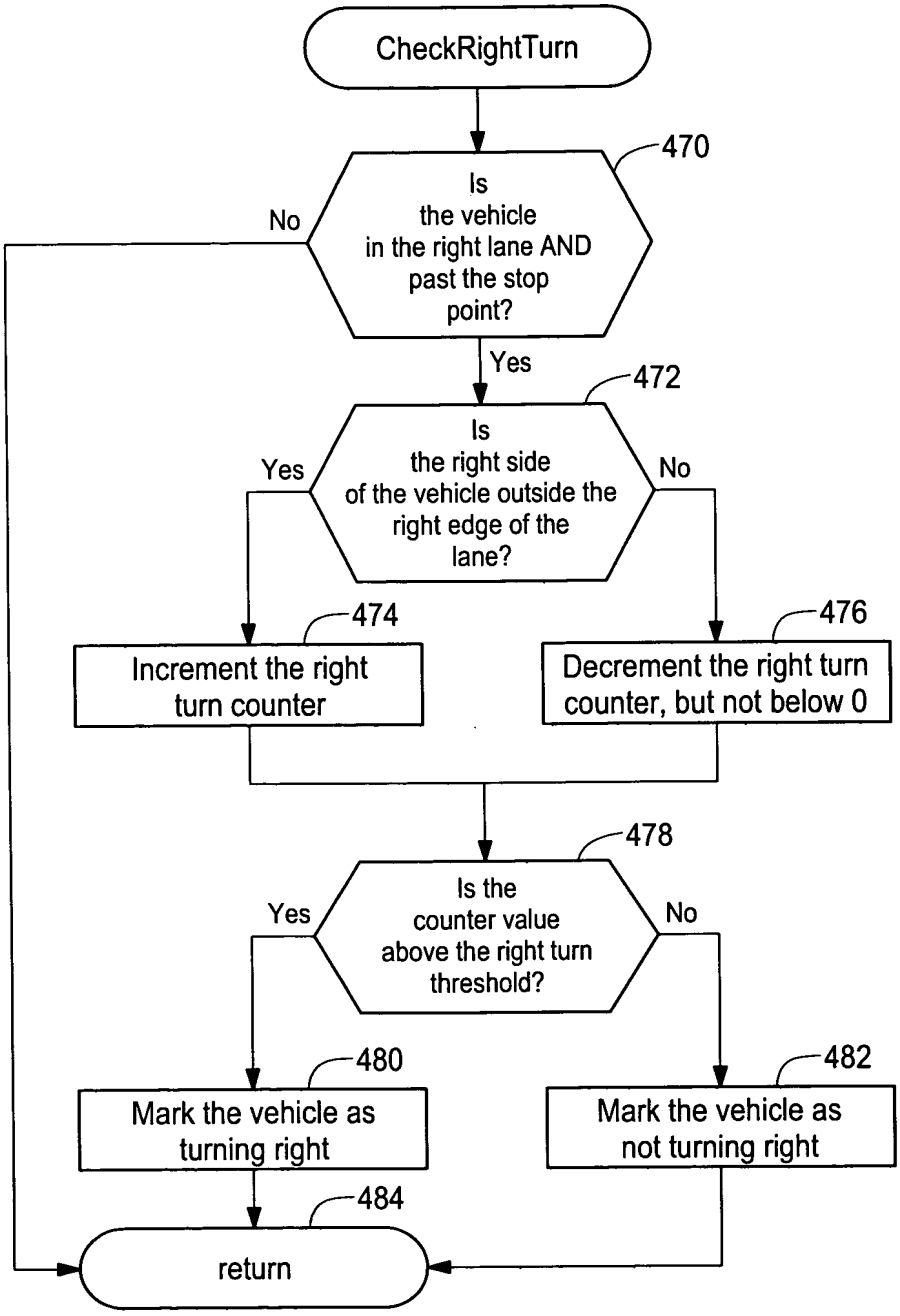

CheckRightTurn
470
Is the vehicle in the right lane AND past the stop point?
No
Yes
472
Is the right side of the vehicle outside the right edge of the lane?
Yes
No
474
Increment the right turn counter
476
Decrement the right turn counter, but not below 0
478
Is the counter value above the right turn threshold?
Yes
No
480
Mark the vehicle as turning right
482
Mark the vehicle as not turning right
484
return

FIG. 16

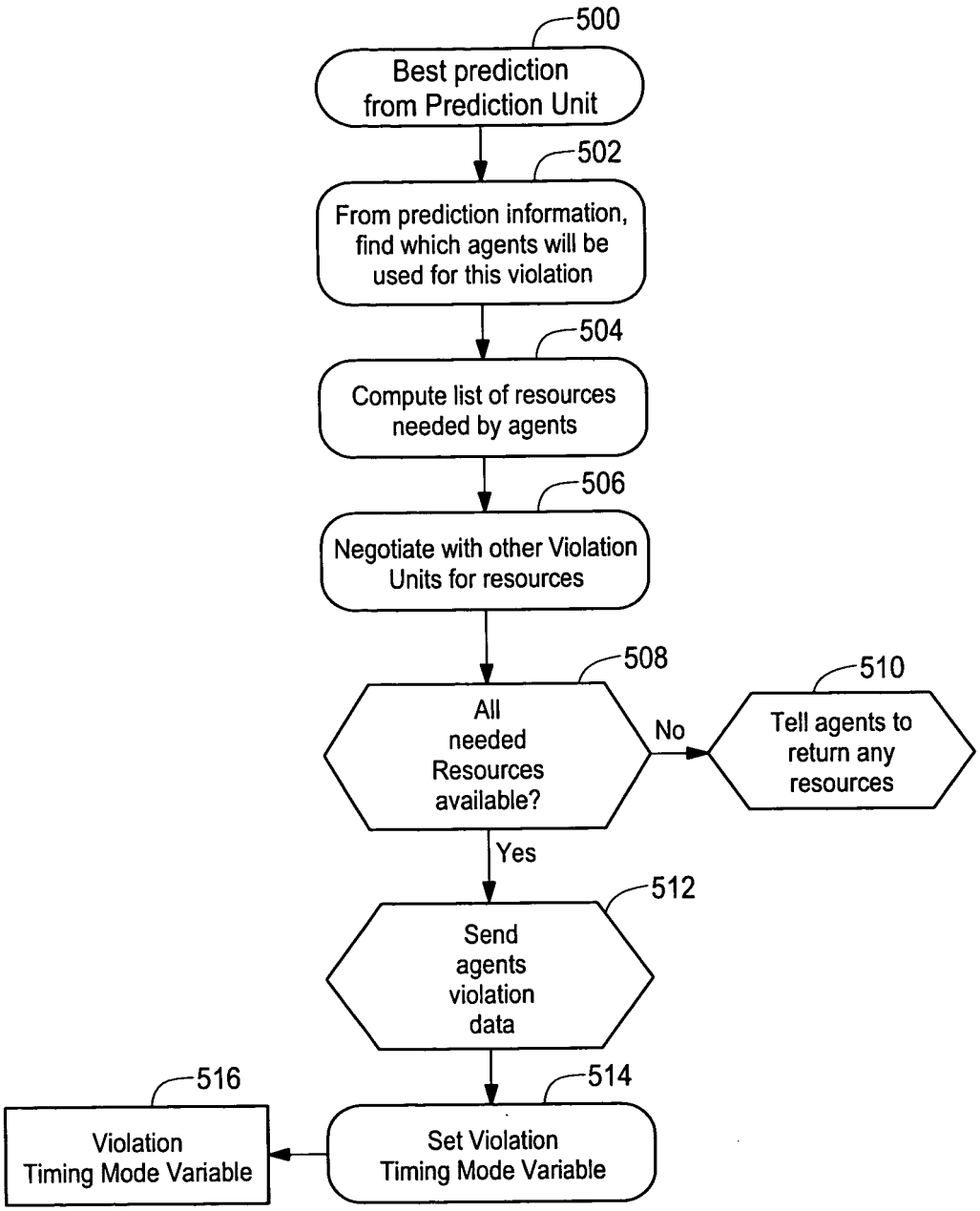

500
Best prediction from Prediction Unit
502
From prediction information, find which agents will be used for this violation
504
Compute list of resources needed by agents
506
Negotiate with other Violation Units for resources
508
All needed Resources available?
No
510
Tell agents to return any resources
Yes
512
Send agents violation data
514
Set Violation Timing Mode Variable
516
Violation Timing Mode Variable

FIG. 17

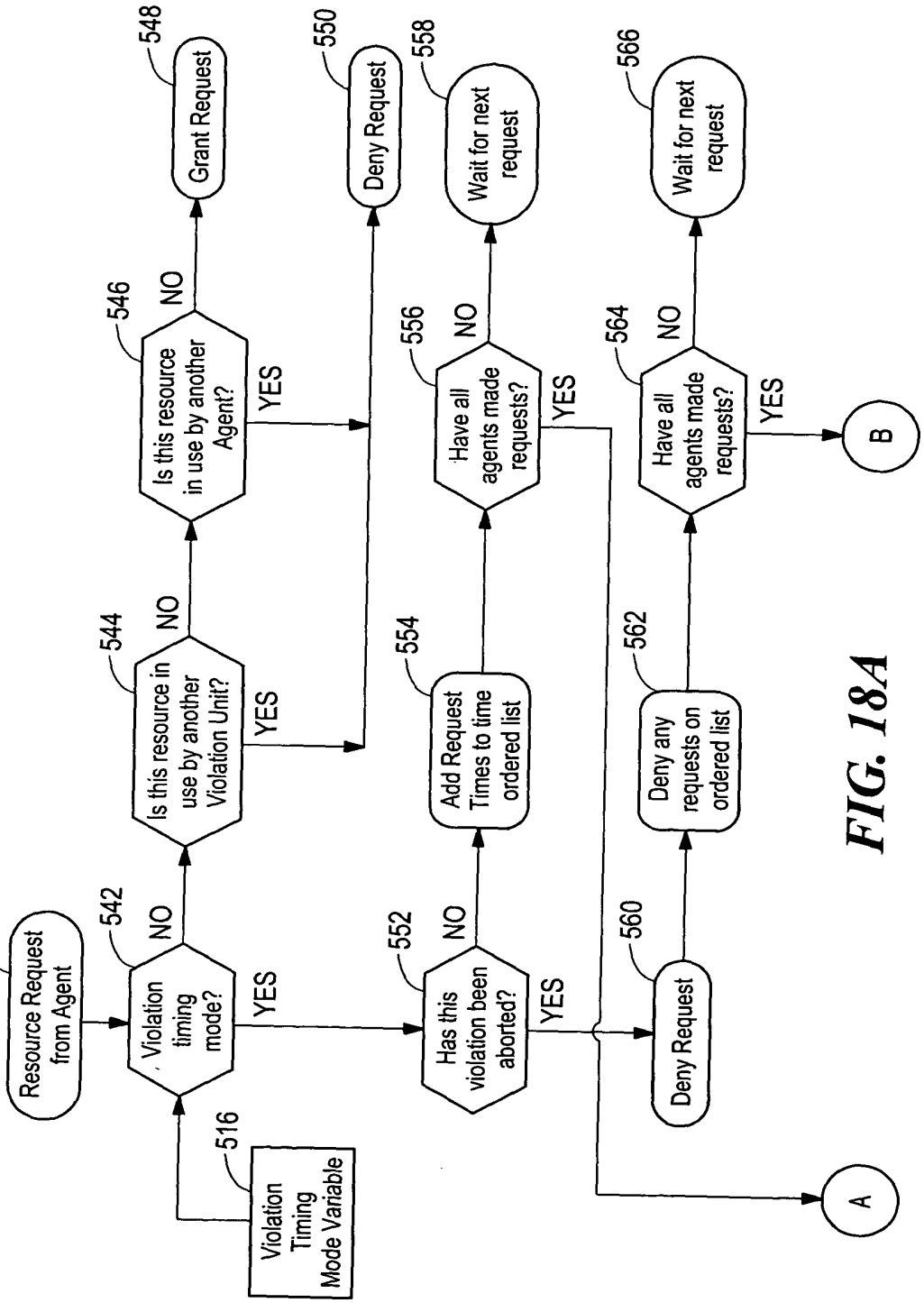

540
Resource Request from Agent
542
Violation timing mode?
NO
YES
516
Violation Timing Mode Variable
544
Is this resource in use by another Violation Unit?
NO
YES
546
Is this resource in use by another Agent?
NO
YES
548
Grant Request
550
Deny Request
552
Has this violation been aborted?
NO
YES
554
Add Request Times to time ordered list
556
Have all agents made requests?
NO
YES
558
Wait for next request
560
Deny Request
562
Deny any requests on ordered list
564
Have all agents made requests?
NO
YES
566
Wait for next request
A
B

FIG. 18A

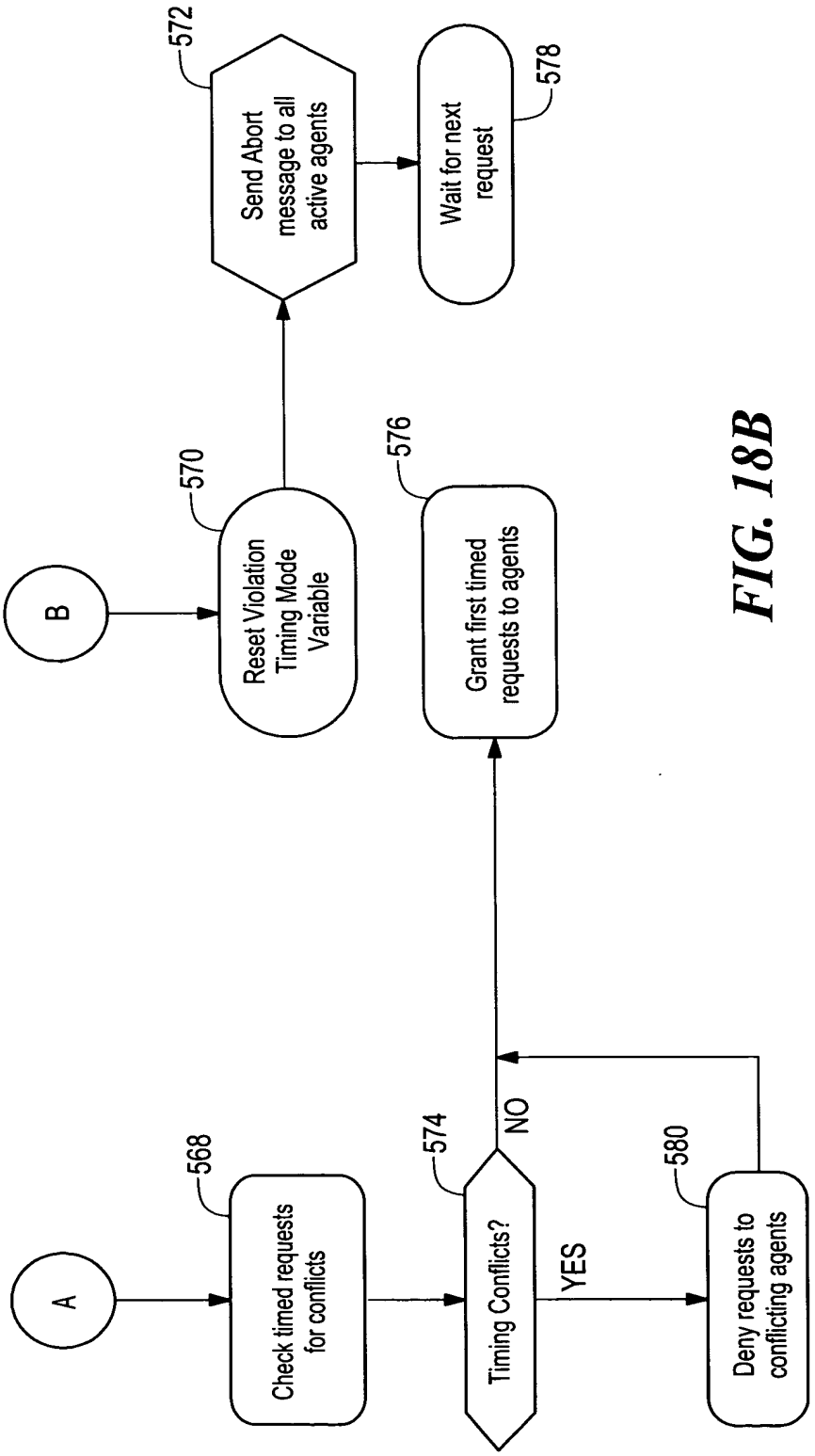

A
568
Check timed requests for conflicts
574
Timing Conflicts?
NO
YES
580
Deny requests to conflicting agents
576
Grant first timed requests to agents
B
570
Reset Violation Timing Mode Variable
572
Send Abort message to all active agents
578
Wait for next request

FIG. 18B

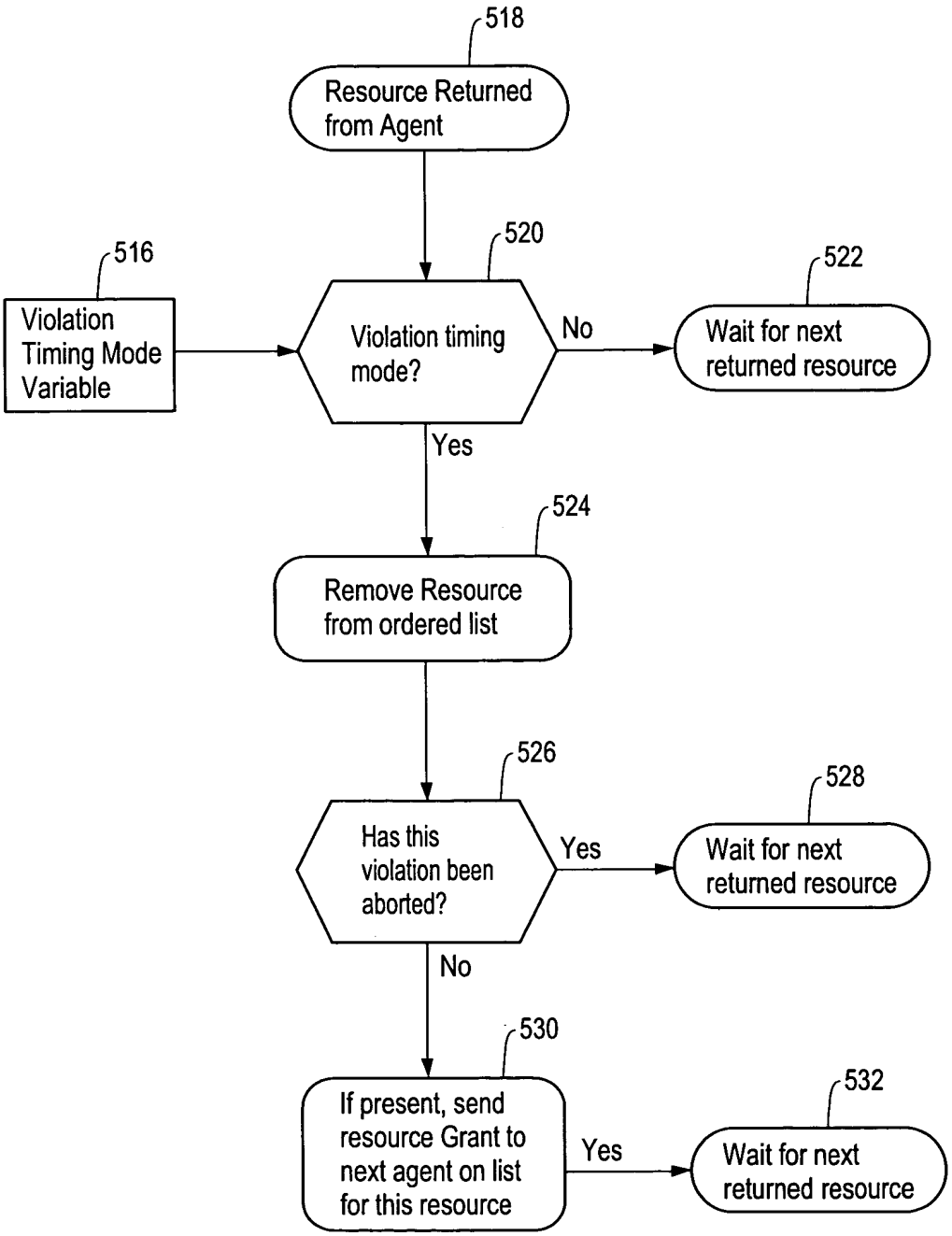

518
Resource Returned from Agent
516
Violation Timing Mode Variable
520
Violation timing mode?
No
522
Wait for next returned resource
Yes
524
Remove Resource from ordered list
526
Has this violation been aborted?
Yes
528
Wait for next returned resource
No
530
If present, send resource Grant to next agent on list for this resource
Yes
532
Wait for next returned resource

FIG. 19

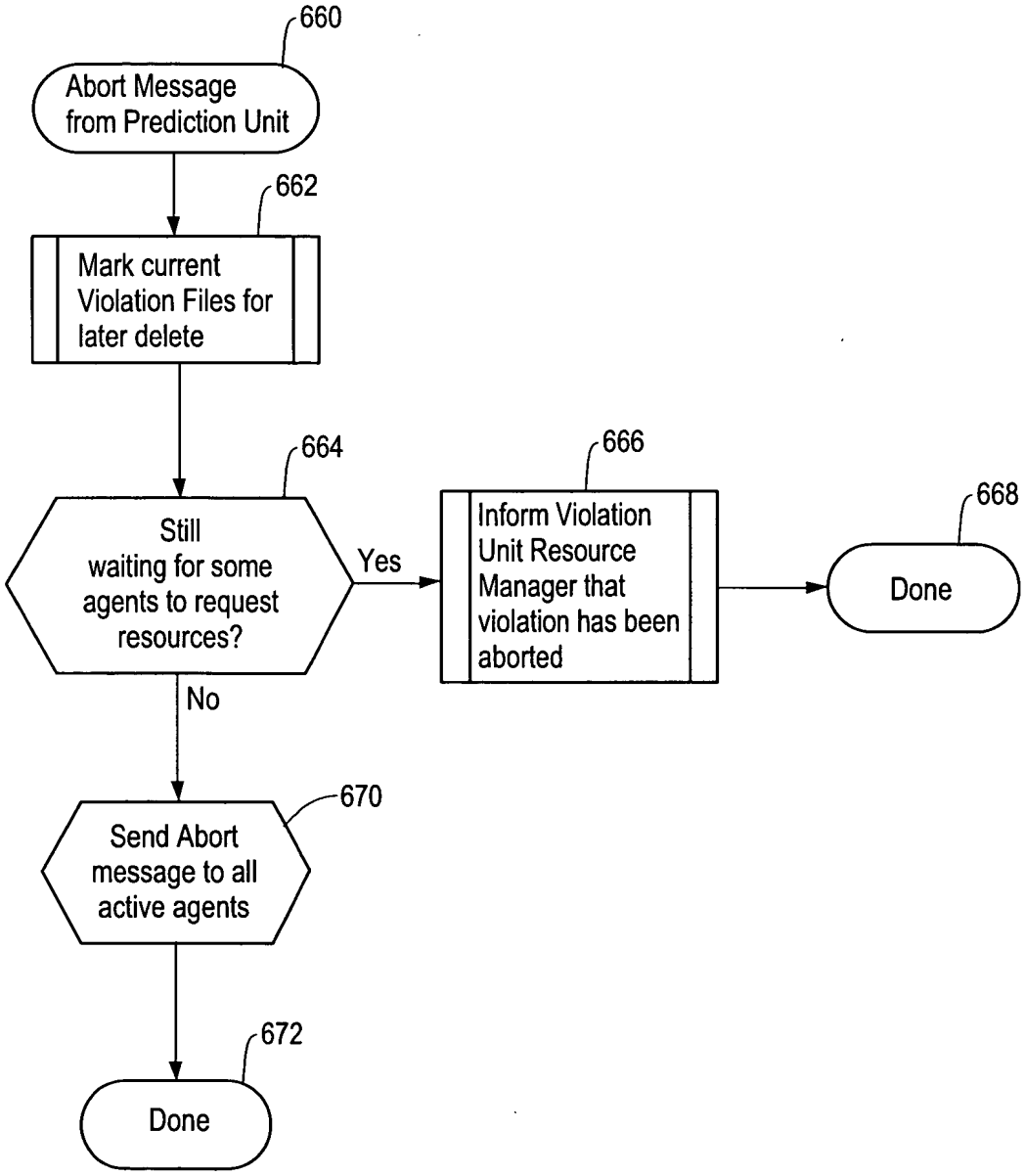

660
Abort Message from Prediction Unit
662
Mark current Violation Files for later delete
664
Still waiting for some agents to request resources?
Yes
666
Inform Violation Unit Resource Manager that violation has been aborted
668
Done
No
670
Send Abort message to all active agents
672
Done

FIG. 20

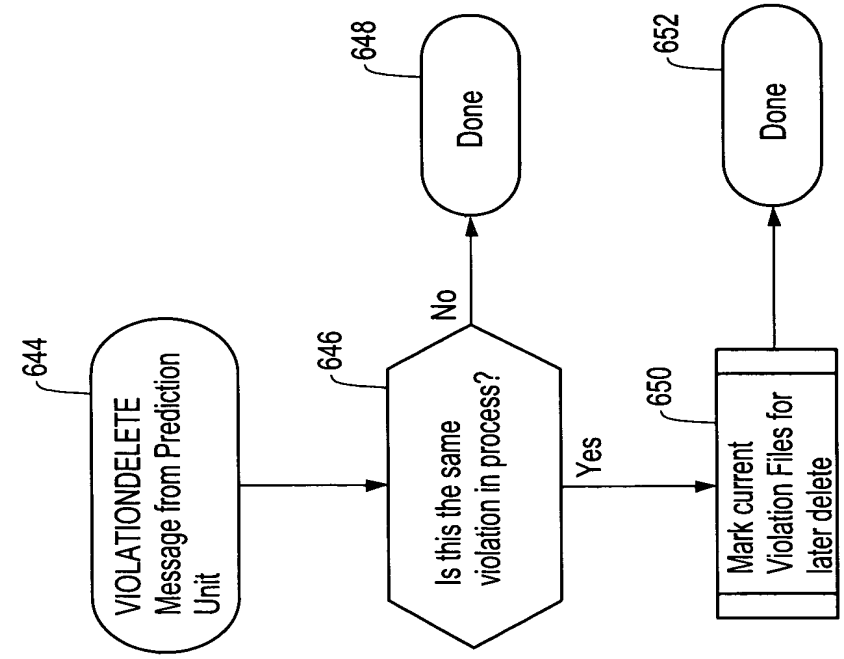

644
VIOLATIONDELETE Message from Prediction Unit
646
Is this the same violation in process?
No
Yes
648
Done
650
Mark current Violation Files for later delete
652
Done

FIG. 23

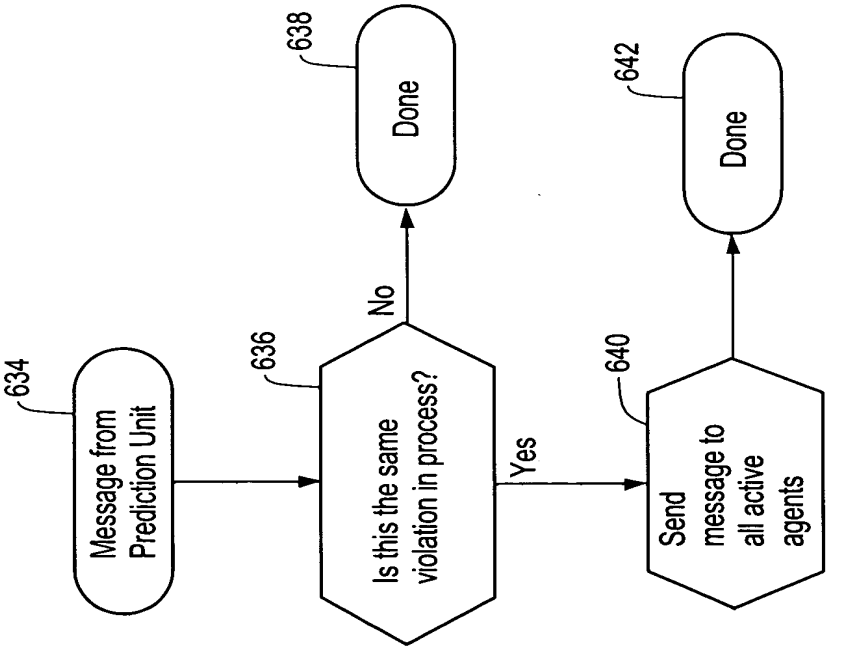

634
Message from Prediction Unit
636
Is this the same violation in process?
No
Yes
638
Done
640
Send message to all active agents
642
Done

FIG. 21

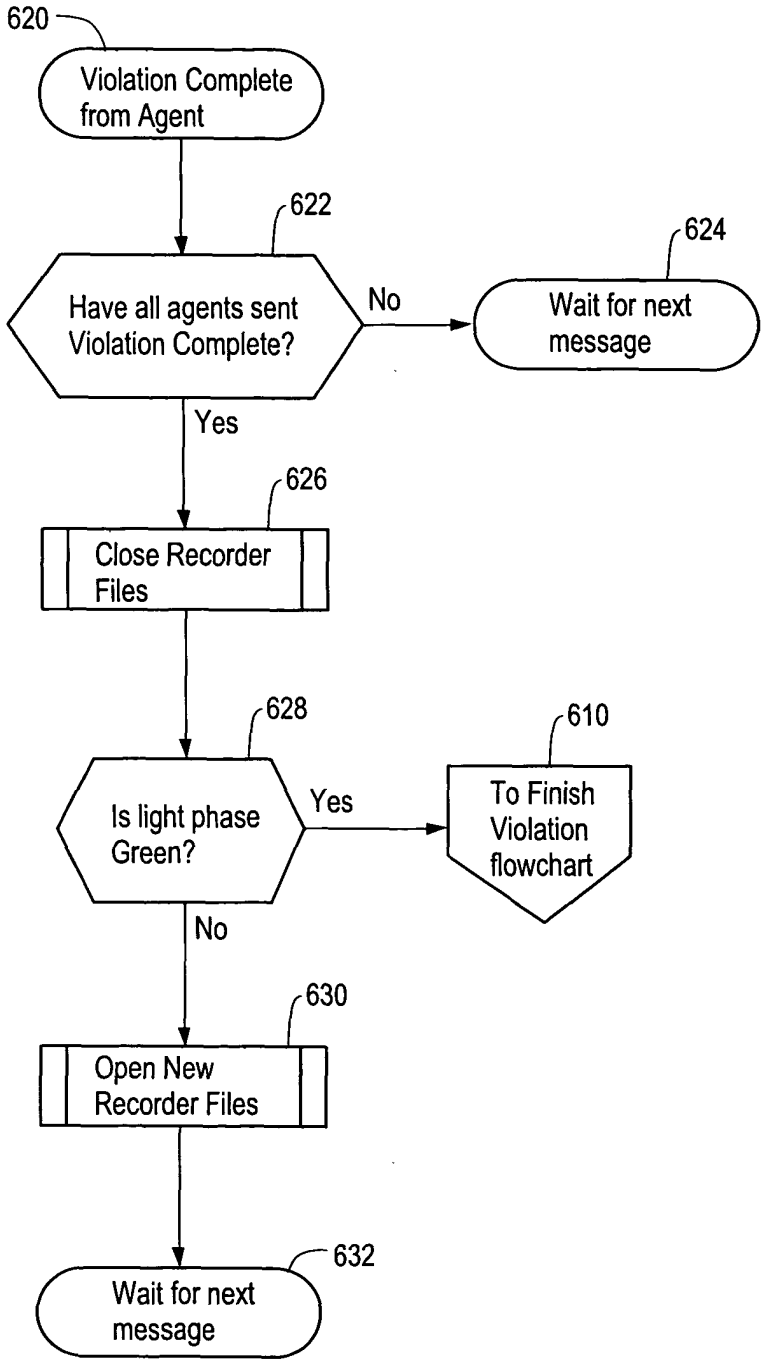
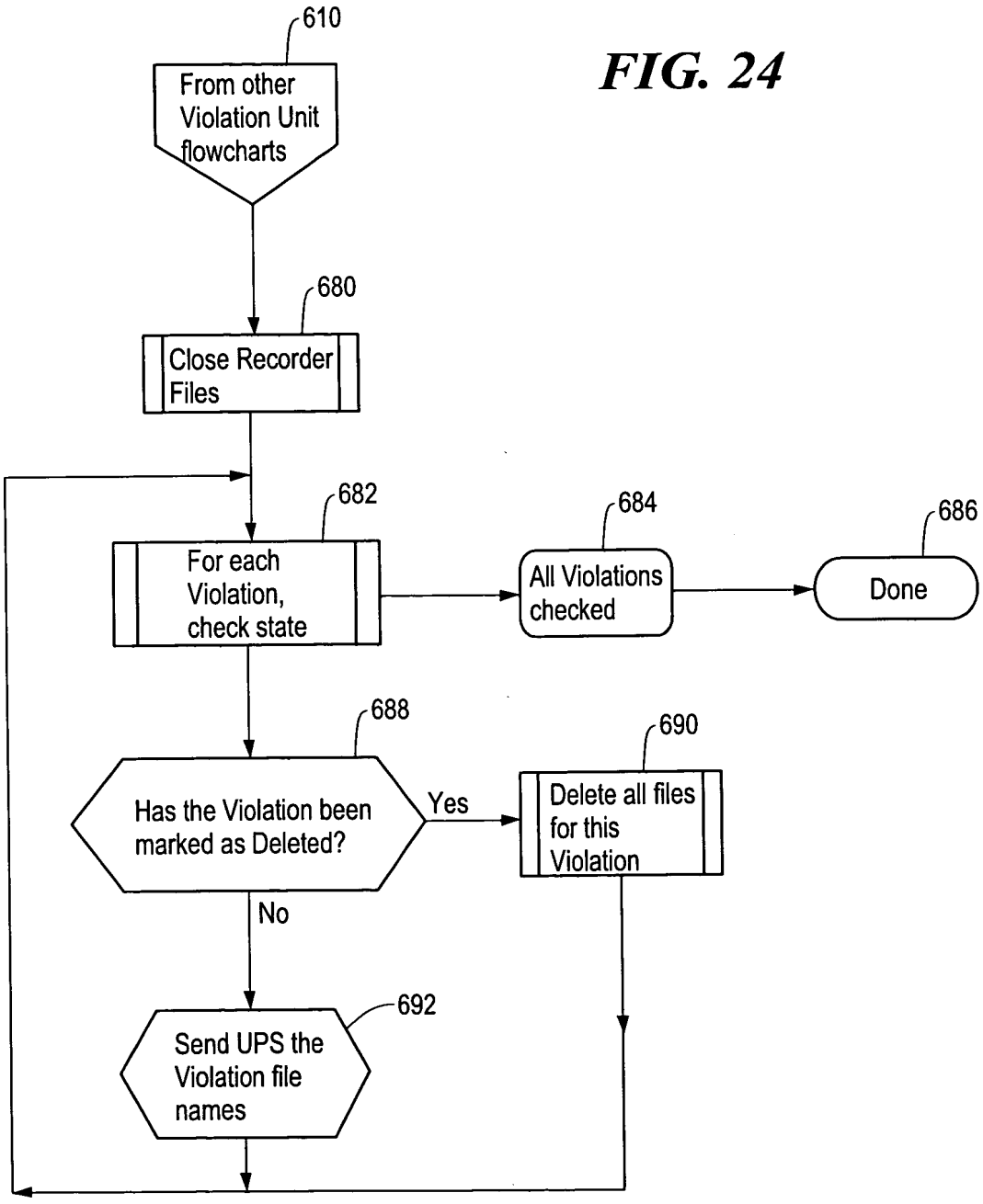

620
Violation Complete from Agent
622
Have all agents sent Violation Complete?
No
624
Wait for next message
Yes
626
Close Recorder Files
628
Is light phase Green?
Yes
610
To Finish Violation flowchart
No
630
Open New Recorder Files
632
Wait for next message

FIG. 22

FIG. 24


610
From other Violation Unit flowcharts
680
Close Recorder Files
682
For each Violation, check state
684
All Violations checked
686
Done
688
Has the Violation been marked as Deleted?
Yes
690
Delete all files for this Violation
No
692
Send UPS the Violation file names

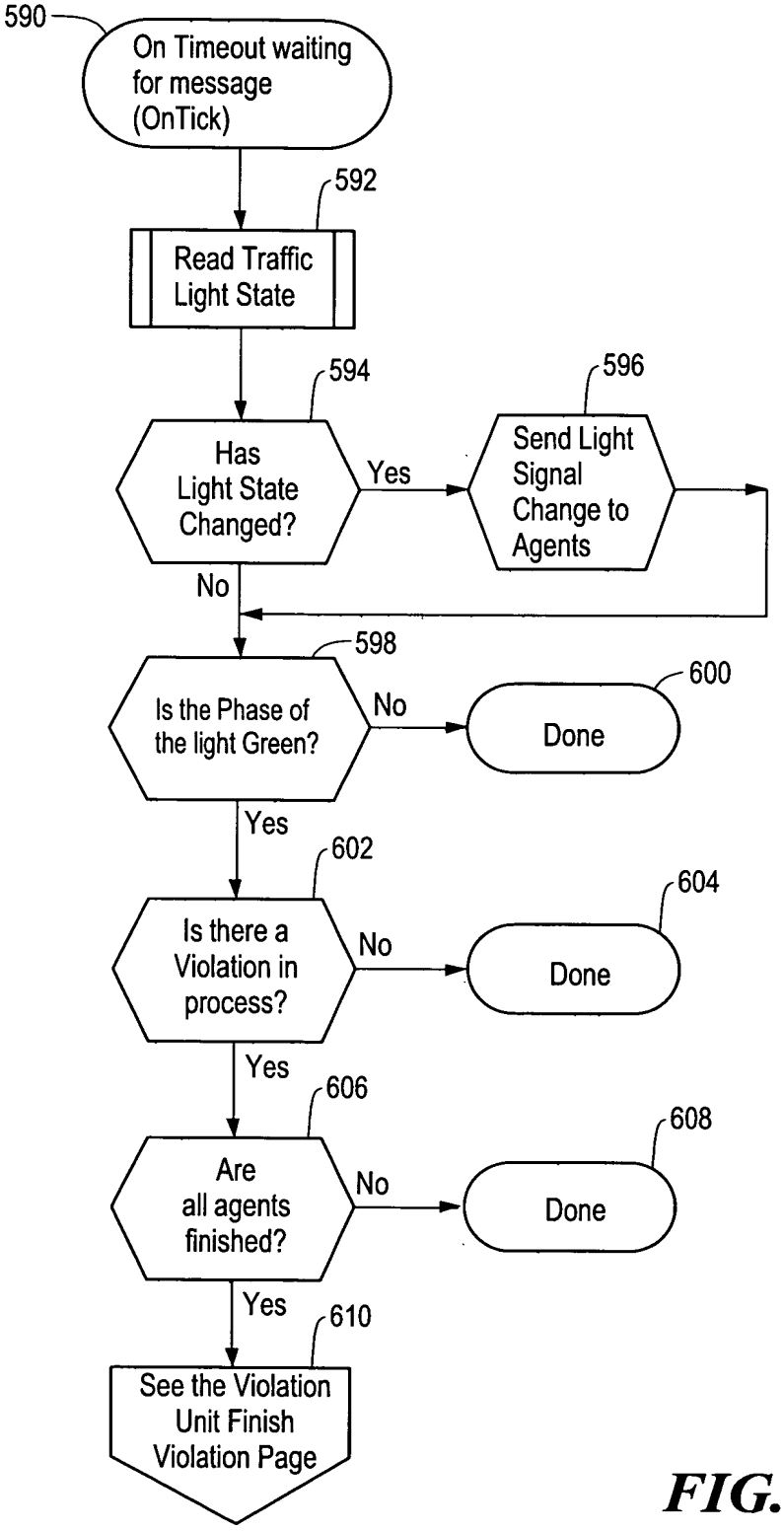

590
On Timeout waiting for message (OnTick)
592
Read Traffic Light State
594
Has Light State Changed?
Yes
596
Send Light Signal Change to Agents
No
598
Is the Phase of the light Green?
No
600
Done
Yes
602
Is there a Violation in process?
No
604
Done
Yes
606
Are all agents finished?
No
608
Done
Yes
610
See the Violation Unit Finish Violation Page

FIG. 25

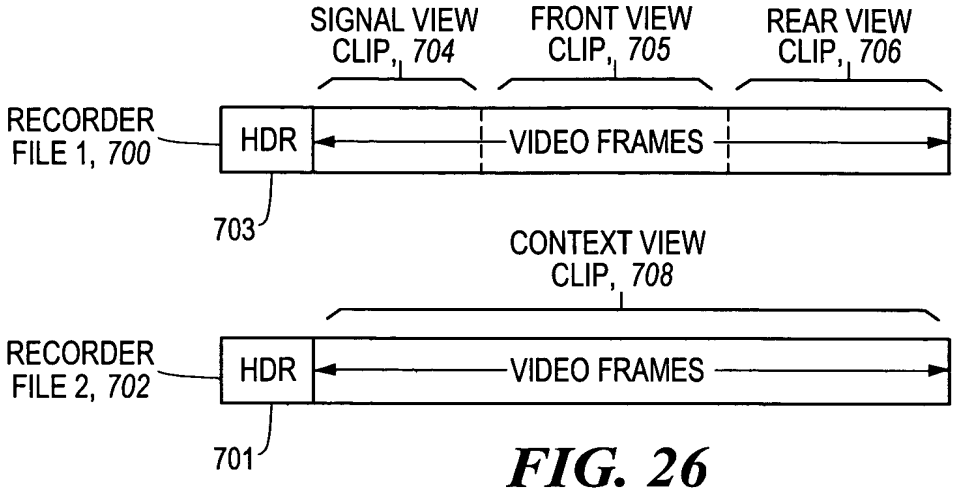

SIGNAL VIEW CLIP, 704
FRONT VIEW CLIP, 705
REAR VIEW CLIP, 706
RECORDER FILE 1, 700
HDR
VIDEO FRAMES
703
CONTEXT VIEW CLIP, 708
RECORDER FILE 2, 702
HDR
VIDEO FRAMES
701

FIG. 26

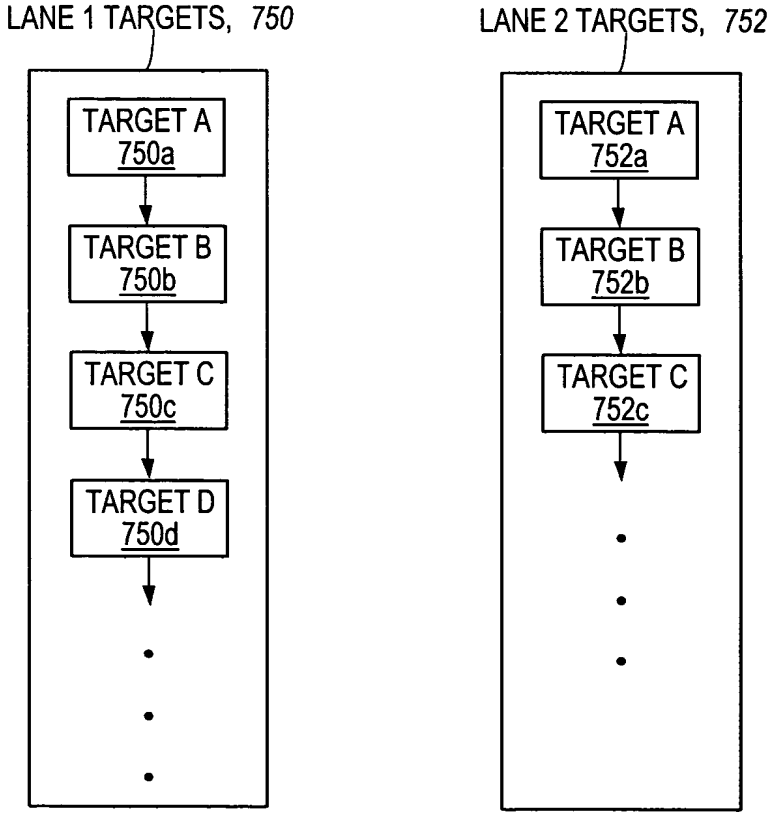

LANE 1 TARGETS, 750
TARGET A 750a
TARGET B 750b
TARGET C 750c
TARGET D 750d
LANE 2 TARGETS, 752
TARGET A 752a
TARGET B 752b
TARGET C 752c

FIG. 27

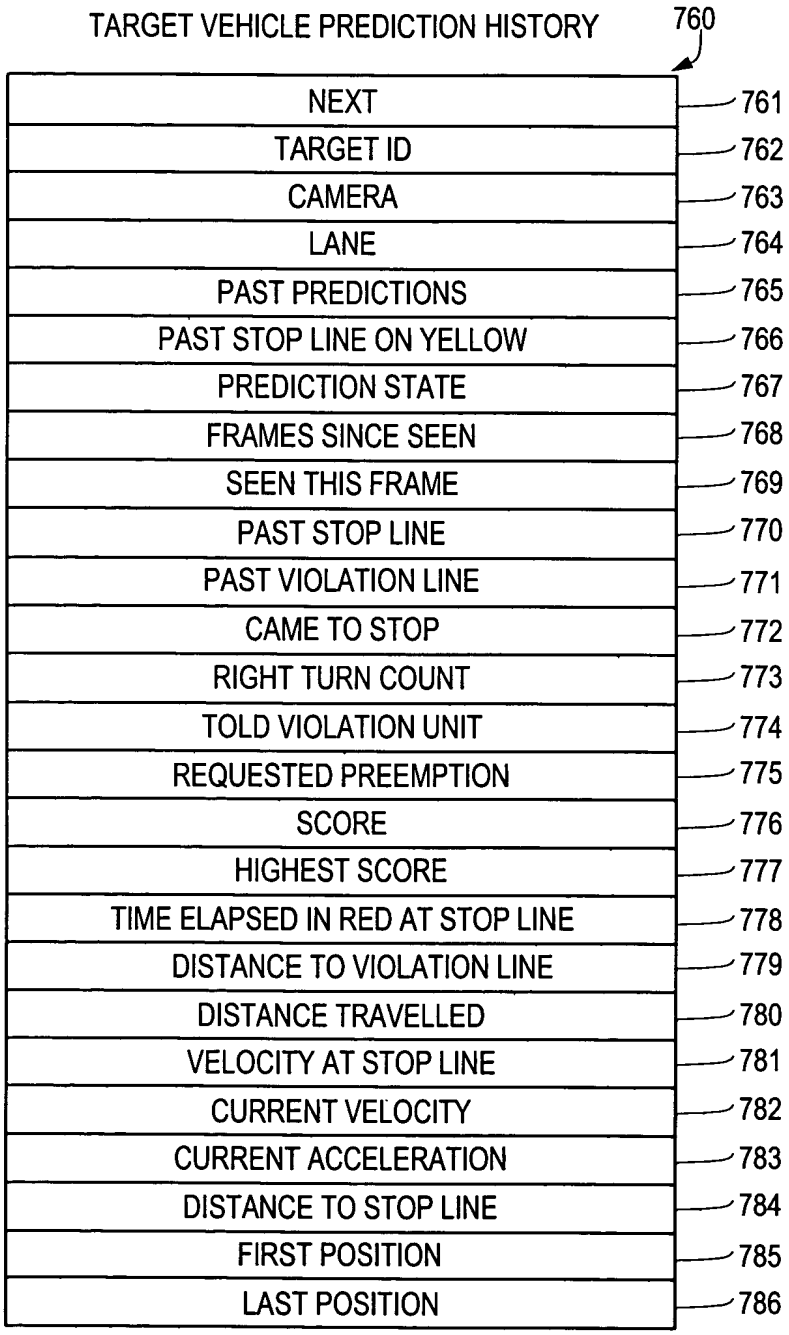

TARGET VEHICLE PREDICTION HISTORY
760
NEXT
761
TARGET ID
762
CAMERA
763
LANE
764
PAST PREDICTIONS
765
PAST STOP LINE ON YELLOW
766
PREDICTION STATE
767
FRAMES SINCE SEEN
768
SEEN THIS FRAME
769
PAST STOP LINE
770
PAST VIOLATION LINE
771
CAME TO STOP
772
RIGHT TURN COUNT
773
TOLD VIOLATION UNIT
774
REQUESTED PREEMPTION
775
SCORE
776
HIGHEST SCORE
777
TIME ELAPSED IN RED AT STOP LINE
778
DISTANCE TO VIOLATION LINE
779
DISTANCE TRAVELLED
780
VELOCITY AT STOP LINE
781
CURRENT VELOCITY
782
CURRENT ACCELERATION
783
DISTANCE TO STOP LINE
784
FIRST POSITION
785
LAST POSITION
786

FIG. 28

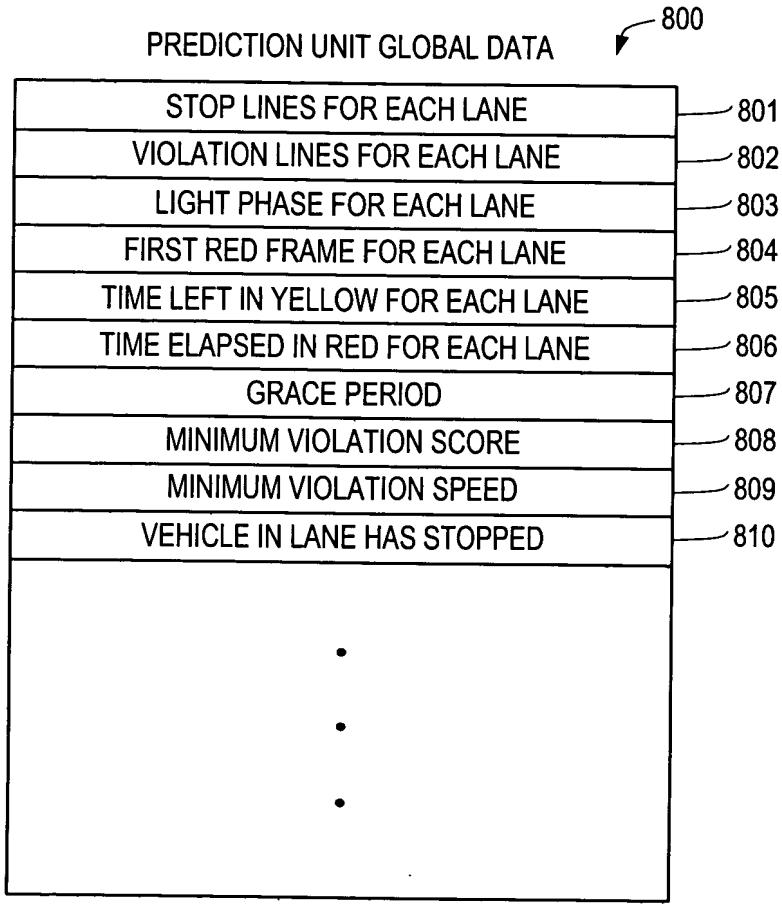

PREDICTION UNIT GLOBAL DATA
800
STOP LINES FOR EACH LANE
801
VIOLATION LINES FOR EACH LANE
802
LIGHT PHASE FOR EACH LANE
803
FIRST RED FRAME FOR EACH LANE
804
TIME LEFT IN YELLOW FOR EACH LANE
805
TIME ELAPSED IN RED FOR EACH LANE
806
GRACE PERIOD
807
MINIMUM VIOLATION SCORE
808
MINIMUM VIOLATION SPEED
809
VEHICLE IN LANE HAS STOPPED
810

FIG. 29

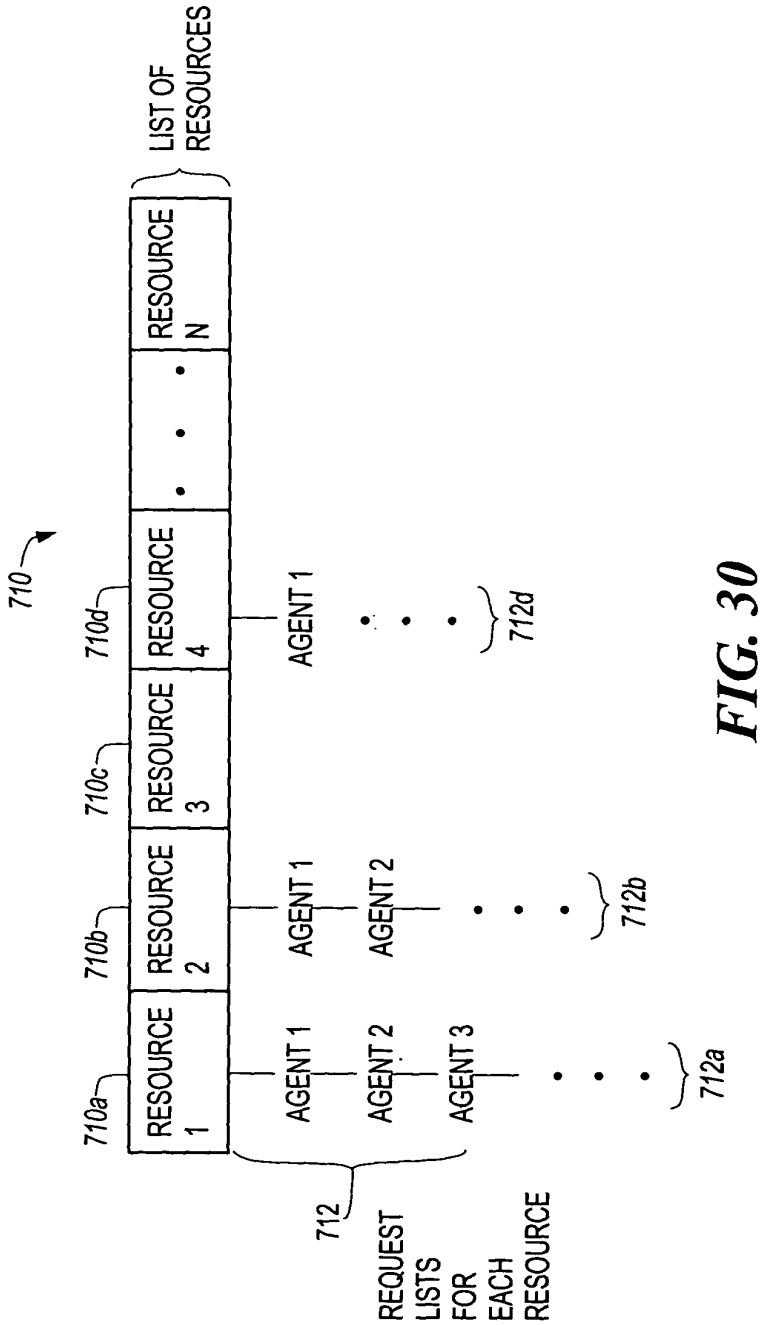

710
LIST OF RESOURCES
RESOURCE 1
RESOURCE 2
RESOURCE 3
RESOURCE 4
RESOURCE N
710a
710b
710c
710d
AGENT 1
AGENT 2
AGENT 3
712a
712b
712d
712
REQUEST LISTS FOR EACH RESOURCE

FIG. 30

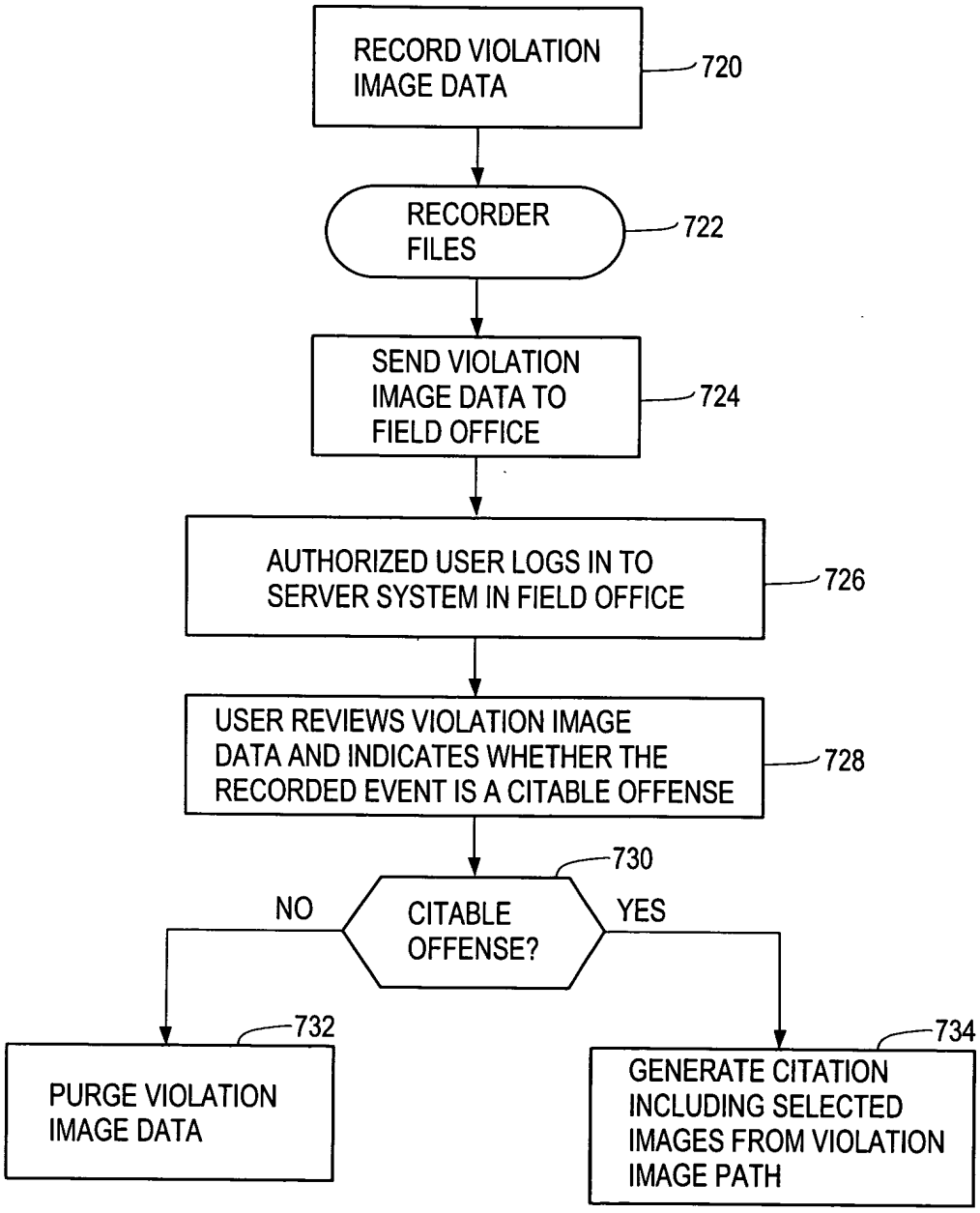

RECORD VIOLATION IMAGE DATA
720
RECORDER FILES
722
SEND VIOLATION IMAGE DATA TO FIELD OFFICE
724
AUTHORIZED USER LOGS IN TO SERVER SYSTEM IN FIELD OFFICE
726
USER REVIEWS VIOLATION IMAGE DATA AND INDICATES WHETHER THE RECORDED EVENT IS A CITABLE OFFENSE
728
730
NO
CITABLE OFFENSE?
YES
732
PURGE VIOLATION IMAGE DATA
734
GENERATE CITATION INCLUDING SELECTED IMAGES FROM VIOLATION IMAGE PATH

FIG. 31

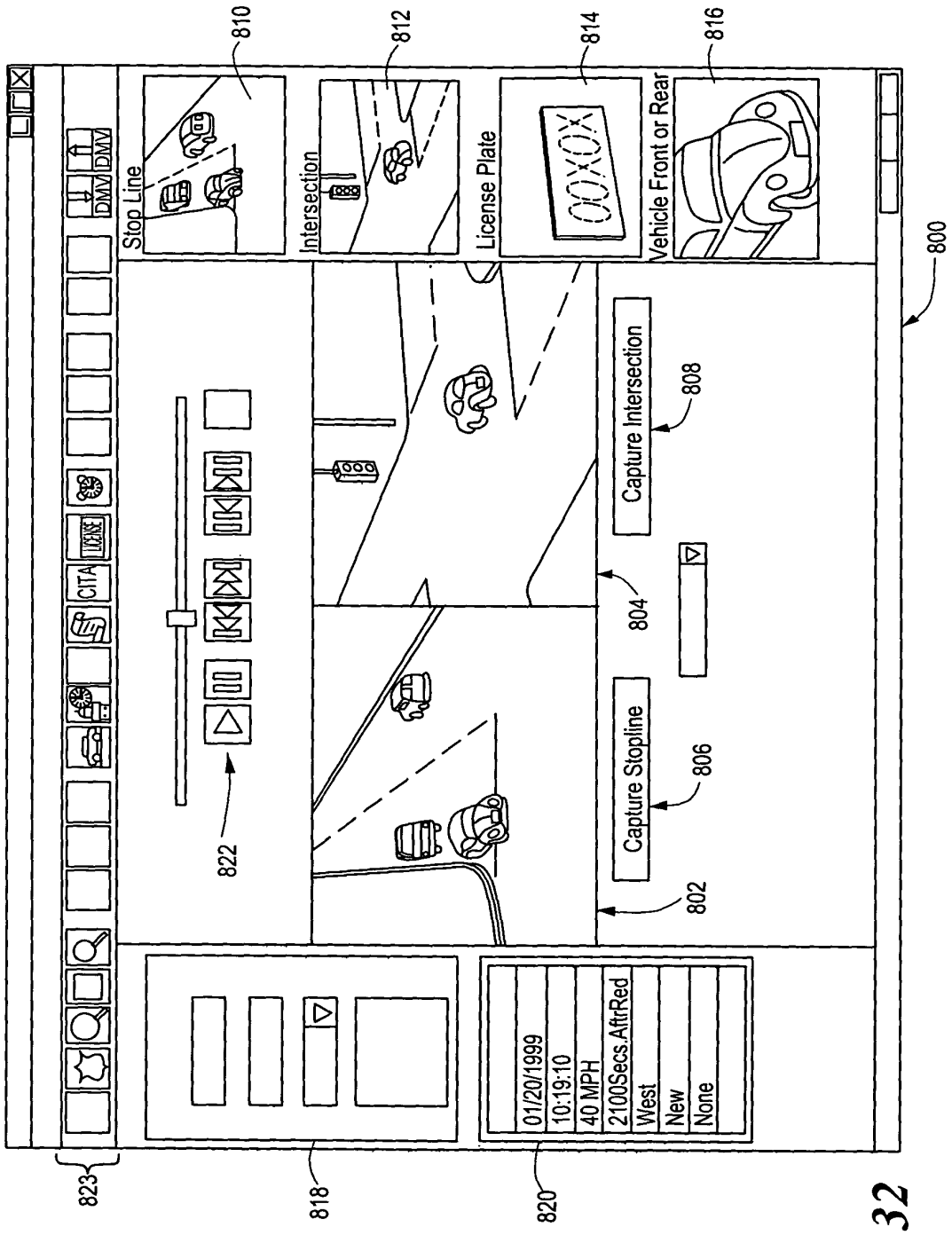

810
812
814
816
Stop Line
Intersection
License Plate
Vehicle Front or Rear
800
Capture Intersection
808
804
Capture Stopline
806
802
822
823
818
820
01/20/1999
10:19:10
40 MPH
2100Secs.AftrRed
West
New
None

FIG. 32

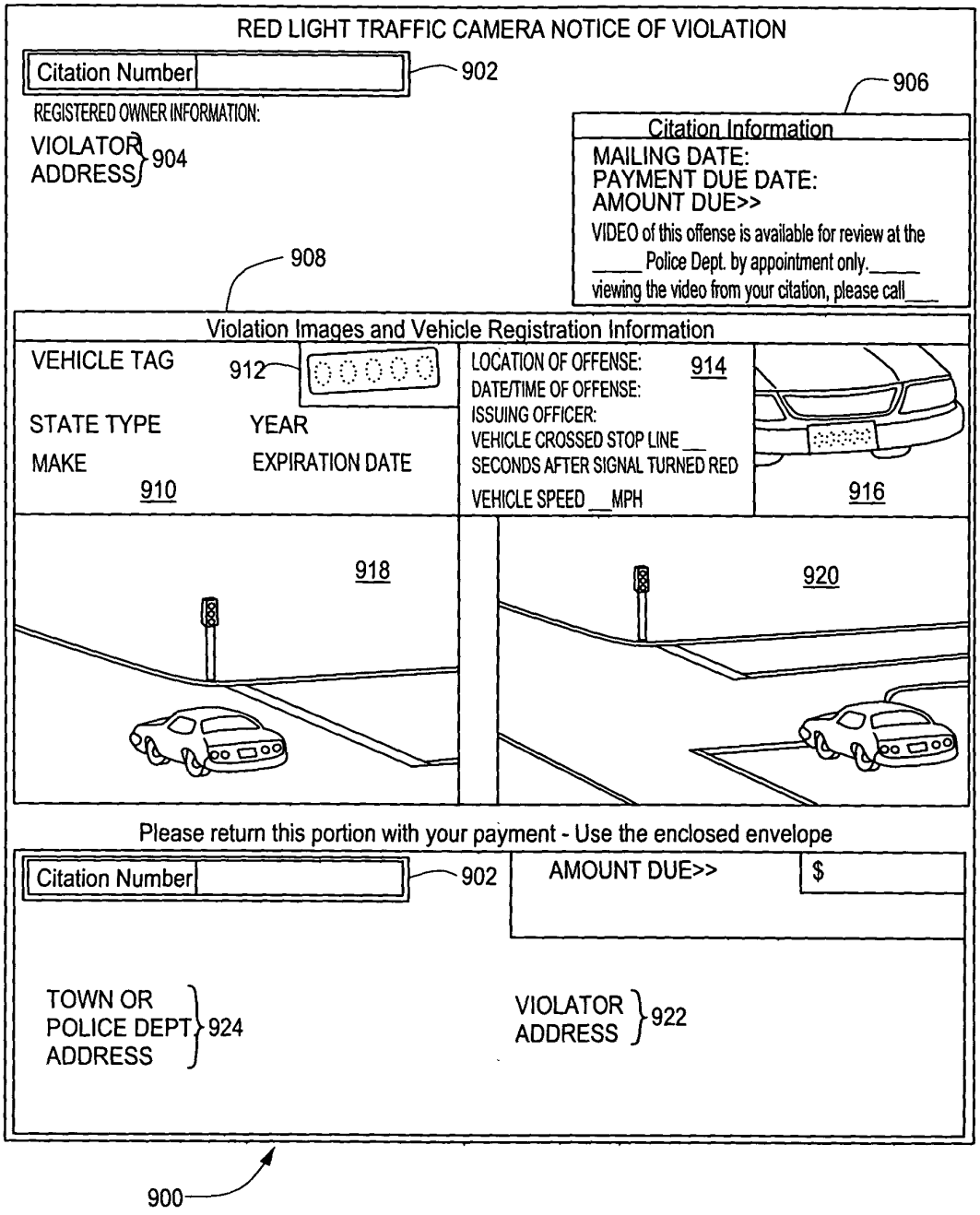

RED LIGHT TRAFFIC CAMERA NOTICE OF VIOLATION
Citation Number
902
906
REGISTERED OWNER INFORMATION:
VIOLATOR ADDRESS
904
Citation Information
MAILING DATE:
PAYMENT DUE DATE:
AMOUNT DUE>>
VIDEO of this offense is available for review at the _____ Police Dept. by appointment only._____ viewing the video from your citation, please call___
908
Violation Images and Vehicle Registration Information
VEHICLE TAG
912
STATE TYPE
YEAR
MAKE
EXPIRATION DATE
910
LOCATION OF OFFENSE:
914
DATE/TIME OF OFFENSE:
ISSUING OFFICER:
VEHICLE CROSSED STOP LINE __
SECONDS AFTER SIGNAL TURNED RED
VEHICLE SPEED __MPH
916
918
920
Please return this portion with your payment - Use the enclosed envelope
Citation Number
902
AMOUNT DUE>>
$
TOWN OR POLICE DEPT ADDRESS
924
VIOLATOR ADDRESS
922
900

FIG. 33

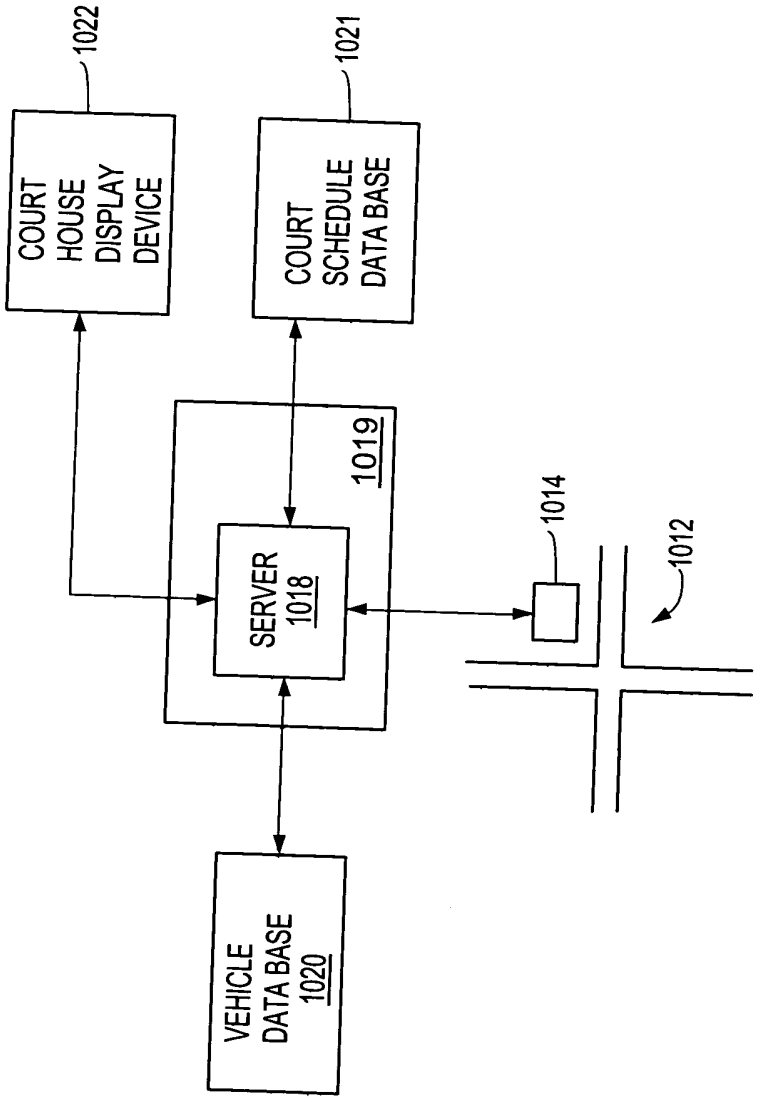

1022
COURT HOUSE DISPLAY DEVICE
1021
COURT SCHEDULE DATA BASE
1019
SERVER 1018
1014
1012
VEHICLE DATA BASE 1020

FIG. 34